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Modélisation d'accompagnement pour l'analyse des interactions entre usages des terres et de l'eau et migrations dans le bassin versant de la Lam Dome Yai au Nord Est de la Thaïlande

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MODÉLISATION D’ACCOMPAGNEMENT POUR L’ANALYSE DES INTERACTIONS ENTRE USAGES DES TERRES, DE L’EAU ET MIGRATIONS DANS LE BASSIN VERSANT DE LA LAM DOME YAI AU NORD-EST DE LA THAÏLANDE

Companion Modelling to analyse the land & water use and labour migration interactions in the Lam Dome Yai watershed, Lower Northeast Thailand

Warong Naivinit

Résumé de la thèse

La thèse porte sur la conception, la mise en œuvre et le suivi-évaluation d’un processus de modélisation d'accompagnement (ComMod pour « companion modelling ») utilisé afin de représenter et d’analyser les interactions entre la gestion des terres rizicoles, les usages de l’eau agricole et les migrations de travailleurs ruraux vers les villes dans un bassin versant du sud de la province d’Ubon Ratchathani au Nord Est de la Thaïlande.

Elle est organisée de la façon suivante : un chapitre introductif, suivi de trois parties composées respectivement de quatre, trois et quatre chapitres, et se termine par un chapitre conclusif. À la suite du chapitre introductif qui cadre les enjeux de gestion des ressources naturelles, mais aussi méthodologiques concernant l’implication d’acteurs. La riziculture non irriguée est l’usage des terres dominant au nord-est de la Thaïlande. La production d’un cycle annuel de riz est contrainte par la distribution erratique des pluies, une longue saison sèche et la texture grossière des sols. Les rendements en paddy sont faibles et les revenus agricoles des ménages peu élevés. Pour la majorité des petits agriculteurs familiaux, les migrations saisonnières ou plus permanente de la main d’œuvre familiale constituent une stratégie d’adaptation fréquente et efficace. Mais elles conduisent à la raréfaction de la force de travail sur nombre d’exploitations et obligent à en ajuster le fonctionnement. Une meilleure compréhension des interactions entre ces migrations et l’usage des terres et de l’eau est nécessaire au moment où les autorités planifient d’importants investissements dans des infrastructures d’irrigation notamment dans le bassin versant de la Lam Dome Yai au sud de la province d’Ubon Ratchathani.

La première partie décrit les différentes facettes pertinentes du contexte de ce cas d'étude à partir d'une revue de la littérature existante et de résultats d'enquêtes de terrain complémentaires. Ainsi les spécificités des conditions géographiques régionales sont abordées (chapitre 2), tout comme leur évolution récente (chapitre 3). Les processus de migrations de travailleurs ruraux qui sont au cœur du sujet sont décrits au chapitre 4, suivis de la présentation d'une typologie des exploitations agricoles locales (chapitre 5).

La deuxième partie s'intéresse à la méthodologie de recherche employée, la modélisation d'accompagnement, replacée dans le contexte des différents types de démarches utilisées en modélisation participative. Le chapitre 6 présente une revue de littérature sur le sujet, tandis que le suivant porte plus spécifiquement sur la démarche ComMod mobilisée ici, avant la discussion de sa mise en œuvre concrète dans l'étude de cas du bassin de la Lam Dome Yai au chapitre 8. La démarche ComMod est utilisée ici pour faciliter le co-apprentissage entre chercheurs et différents types de riziculteurs à propos de ces interactions. Itérative et évolutive, elle favorise le partage de connaissances au cours d'un processus interdisciplinaire de recherche-action renforçant les capacités d'adaptation et d'anticipation des acteurs. ComMod vise aussi ici à faciliter l'intégration des connaissances autochtones, d'experts et académiques sur la gestion des exploitations.

La troisième partie est centrée sur les résultats obtenus et s'organise autour de la présentation de l'utilisation des principaux outils mobilisés avec les ménages de riziculteurs du village de Ban Mak Maï. Ainsi les jeux de rôles successifs utilisés avec eux sont décrits au chapitre 9 et le modèle informatique multi-agents construit durant ce processus ComMod au chapitre 10. Le chapitre 11 présente et analyse les résultats des simulations informatiques réalisées : d'abord sur le terrain, avec les villageois de Ban Mak Mai (village ayant donné son nom au modèle informatique BMM), puis au laboratoire où des simulations complémentaires finales ont été réalisées afin d'approfondir l'exploration de la question examinée au moyen de l'outil informatique co-construit avec les riziculteurs. Le chapitre suivant constitue une évaluation réflexive sur les effets et l'impact de la mise en œuvre de la modélisation d'accompagnement sur les différents types de participants qui y ont pris part (chapitre 12), tandis que la conclusion tire les leçons de cette étude de cas et propose des recommandations afin d'améliorer l'usage de tels processus de modélisation participative.

Le chapitre introductif montre que la variabilité de la disponibilité en eau ainsi qu'en main d'œuvre agricole sont des contraintes importantes du développement agricole régional et plus particulièrement en riziculture inondée, activité économique dominante dans la région étudiée. En l'absence de système d'irrigation collectif, l'alimentation en eau des petits casiers rizicoles se fait ici par la pluie (lors des six mois de saison humide), le transfert d'eau par gravité d'un casier à un autre, ainsi que le pompage à partir des petits bassins de stockage individuels qui se sont multipliés durant les deux dernières décennies. Mais la compréhension encore limitée des interactions complexes entre usage agricole des terres, de l'eau et migrations de travailleurs, tant dans le monde académique et des décideurs de la politique agricole, que sur les exploitations agricoles elles-mêmes, fait courir un risque d'échec important aux ambitieux programmes de développement des ressources en eau agricole actuellement envisagés par les autorités gouvernementales dans cette région relativement pauvre du royaume. Dans ce contexte, la thèse vise à tester si la démarche ComMod peut améliorer cette connaissance, conduire à une représentation partagée de ces interactions en intégrant les connaissances pertinentes de sources et nature variées, tout en créant de nouveaux savoirs ainsi que d'autres effets sur les participants. Le type de représentation commune visé est un simulateur informatique qui, une fois validé, sera utilisé pour la simulation et l'exploration de différents scénarios futurs possibles identifiés par les participants villageois ou choisis par l'équipe de recherche.

Le chapitre 2 fournit les connaissances pertinentes nécessaires afin de comprendre le contexte géographique d'un point de vue assez global tout d'abord, en replaçant la région d'étude dans le paysage national, puis au moyen de la description des caractéristiques bio-physiques clefs (fortes contraintes géologiques, pédologiques et climatiques déterminant le fonctionnement hydrologique des petits bassins versants rizicoles) qui déterminent assez largement l'éventail, ici limité, des différents types d'activités agricoles possibles ainsi que leurs relations avec l'emploi de main d'œuvre hors-exploitation. La présentation des principales productions agricoles et des structures agraires locales permet aussi de souligner les caractères originaux de la riziculture inondée locale (un foyer de la production de riz parfumé de qualité à haute valeur commerciale) ainsi que des conditions socio-économiques (démographie, infrastructures économiques, croissance régionale, etc.) dans lesquelles elle est pratiquée. Ce chapitre campe les éléments de contexte considérés comme a priori importants avant l'analyse de leurs dynamiques récentes.

Le chapitre 3 rend compte des transformations agraires récentes et des changements d'usage des terres dans le contexte géographique de la région étudiée. Il montre notamment l'importance du pilotage exogène des systèmes de production agricole par le passé, notamment au moyen de l'application de politiques économiques ou de développement d'infrastructures (de communication par exemple) qui ont fortement influencé la mobilité croissante des actifs ruraux au Nord-Est de la Thaïlande. En matière d'usage des terres, si le recul du couvert forestier a accompagné des vagues successives d'expansion de cultures industrielles (manioc, roselle et kénaf, et plus récemment hévéa) depuis les années soixante, la large domination des rizières inondées plantées en riz parfumés glutineux ou non demeure une constante. Les projets hydrauliques gouvernementaux de taille moyenne ou, plus récemment, à petite échelle se sont multiplié durant les toutes dernières décennies afin d'améliorer le contrôle de l'eau dans les rizières et, par endroits, promouvoir la double culture annuelle.

Le chapitre 4 traite ensuite la question, centrale dans cette thèse, des différents types de migrations de main d'œuvre pratiquées dans cette région, de leurs relations avec les conditions climatiques (longue saison sèche de novembre à avril notamment) ainsi que de leurs effets sur les pratiques agricoles et plus particulièrement rizicoles. Ces phénomènes migratoires sont sources de contraintes pour la conduite des systèmes de culture, mais aussi de revenus externes à l'exploitation bienvenus. Diverses adaptations des pratiques culturales peuvent conduire par exemple à la mécanisation de certaines opérations, ou au passage du repiquage au semis direct du riz afin d'économiser de la main d'œuvre. L'analyse est replacée dans l'histoire des processus migratoires en Thaïlande du Nord Est, notamment leur relation avec les phases successives de la croissance économique nationale. Puis les types de migrations identifiés sont reliés à des modèles de décision sous-jacents au niveau de la cellule familiale au moyen de la mobilisation de plusieurs points de vue disciplinaires favorisant les facteurs micro et macro économiques, mais aussi sociaux (réseaux de relations).

Le chapitre 5 approfondit la caractérisation de l'hétérogénéité du milieu rural local en présentant une typologie des exploitations agricoles de la région en trois grandes catégories en fonction de leurs objectifs et stratégies socio-économiques (notamment leurs relations aux marchés des produits et de la main d'œuvre), ainsi que de leurs moyens de production disponibles, la combinaison des productions et activités économiques adoptées. Cette typologie rend aussi compte de la diversité des relations aux migrations et aux revenus de salariat non agricole entre ces différentes catégories de riziculteurs. Une analyse rétrospective des changements survenus chez ces grands types d'exploitants depuis 1994 est aussi fournie. Cette typologie, qui s'exprime essentiellement par la taille des exploitations agricoles et l'intégration dans le marché de produits agricoles, est présentée comme un moyen de faire le « casting » des différentes catégories d'agriculteurs à prendre en compte pour une démarche de modélisation d'accompagnement soucieuse de la diversité des situations familiales. Ceci est nécessaire afin de juger de l'importance relative des migrations de main d'œuvre par type d'exploitant et de leurs conséquences sur les pratiques agricoles. Cela contribue aussi à documenter la complexité de la problématique centrée sur la gestion de l'eau et des rizières et les migrations de travailleurs familiaux.

La deuxième partie débute avec le chapitre 6 et porte elle sur les aspects méthodologiques centraux dans le travail mené, notamment le choix et l'usage d'une démarche de modélisation collaborative adaptée. Ce chapitre propose une revue de la littérature sur les questions de modélisation collaborative au moyen de la comparaison de différentes démarches selon les niveaux de collaboration atteints lors des différentes phases de formulation de la question à examiner, de la conception du modèle, de son implémentation, sa vérification, sa calibration et sa validation, ainsi que lors de son usage et du suivi-évaluation des effets des modèles construits. La composition variable des groupes d'acteurs mobilisés est aussi abordée : types de participants et leurs niveaux d'implication à différents stades du processus de modélisation. Ensuite une comparaison plus approfondie de six démarches de modélisation participative est effectuée à partir d'autant d'études de cas représentatives des méthodes de cartographie cognitive et « soft systèmes », systèmes dynamiques, systèmes multi-agents, analyse multi-critères, méthode statistique et probabiliste et enfin la cartographie spatiale.

Le chapitre 7 est lui focalisé sur la présentation détaillée de la démarche de modélisation d'accompagnement choisie pour cette étude de cas. Il décrit l'origine et l'historique de l'approche ComMod, ses fondements théoriques multiples, ses objectifs et principaux principes méthodologiques ayant trait à la posture du chercheur, la pratique de processus itératifs et évolutifs, l'alternance de travaux de terrain et en laboratoire, etc. Les deux principaux contextes pour son usage (1 : comprendre un système complexe, ou 2 : faciliter la prise de décision dans la gestion collective de ressources) sont aussi abordés et le rattachement de l'étude de cas traitée au premier est justifié. La suite présente les étapes successives d'un processus ComMod ainsi que les outils mobilisés, depuis l'initialisation, la co-conception et co-construction de modèles avec les parties prenantes, l'implémentation et la validation des modèles, l'identification de scénarios pertinents à simuler, leur exploration et évaluation collective, et enfin le suivi-évaluation des effets et de l'impact de ces activités sur les participants. Ce chapitre se termine par la présentation des sujets d'actualité au sein du groupe ComMod, notamment à propos des changements d'échelles et de la prise en compte des relations de pouvoir durant de tels processus participatifs. Il permet ainsi de bien situer la thèse dans l'actualité des questions en cours de discussion dans le réseau de praticiens de la démarche ComMod.

Le chapitre 8, richement illustré, décrit les quatre séquences successives du processus ComMod piloté par l'auteur et les choix effectués pour la mise en œuvre concrète de la modélisation d'accompagnement sur son terrain d'étude dans la partie centrale du bassin versant de la Lam Dome Yai. Les étapes successives sont détaillées, depuis la sélection du village et des participants, la conception et l'exécution du processus sur plusieurs années (une figure synthétisant l'ensemble), ainsi que pour chacune des séquences les objectifs spécifiques poursuivis, les méthodes et principaux outils mobilisés, tout comme les principaux résultats obtenus au fil de ce long processus. En particulier, le passage graduel de l'usage de modèles reposant sur des jeux de rôles à la co-construction d'un modèle informatique multi-agents est finement décrit. Ce chapitre clé de la thèse s'achève avec la présentation synthétique de la « famille de modèles » produits au court de ce processus de modélisation collaborative ayant associé jeux de rôles et modèle multi-agents informatisé à d'autres techniques complémentaires (différents types de visualisation des processus et la conduite d'enquêtes complémentaires ciblées notamment) en fonction des évènements survenus sur le terrain ainsi que des souhaits des participants. Cette pluralité d'accès à l'information est importante, ainsi que la façon de gérer une réelle implication des acteurs locaux au cours de la modélisation collaborative. De façon tout à fait originale, ici les participants sont tour à tour joueurs, co-concepteurs, « consultants » puis même enseignants auprès d'étudiants en Master à l'université régionale.

Le chapitre 9 présente de façon détaillée et très illustrée les trois jeux de rôles successifs qui ont été conçus et utilisés durant les premières séquences de ce processus ComMod. Leur présentation est organisée selon le protocole ODD pour « Overview » (objectif, variables d'état et échelles, processus et unités de temps) – « Design concepts » et « Details » (initialisation, inputs, sous-modèles). Des diagrammes UML (« Unified Modelling Language ») de classes et de séquence, ainsi que des schémas des dispositifs spatiaux utilisés dans les salles où se sont déroulés les séances de jeu, sont utilisés afin de décrire la structure, les composantes, les processus modélisés, ainsi que les étapes du déroulement des séances de jeu.

Le chapitre 10 porte sur la présentation du modèle informatique multi-agent final (appelé modèle BMM du nom du village de Ban Mak Mai) co-construit avec les riziculteurs. La description détaillée du modèle est faite selon le même protocole ODD qu'au chapitre précédent. Ce chapitre inclut de nombreux diagrammes UML (de classes, de séquence et d'activités), ainsi qu'une description précise des différents parameters pris en compte, de leurs valeurs et de l'origine de l'information utilisée. Les choix effectués pour la représentation des principales composantes du modèle et processus simulés sont argumentés, tandis que les procédures utilisées pour les tests de calibration, vérification et de validation de ce modèle informatique sont également données. Le modèle est composé de cinq entités interdépendantes : individu, ménage agricole (trois grands types d'exploitations), village, riz et bassins. La résolution spatiale de l'interface, représentant quatre exploitations (deux grandes et deux petites) et différents types de rizières le long de la pente, est de 0,04 ha. Chaque exploitation est caractérisée par des rizières de tailles variées, plusieurs types de membres de la maisonnée et un rapport surface cultivée par actif familial. Le modèle opère sur un pas de temps journalier, celui de la prise de décision des riziculteurs et du recueil de la pluviométrie dans la réalité. Il peut aussi réagir à des évènements particuliers : un stress hydrique dans les pépinières déclenchera une réaction des agriculteurs. Les simulations sont effectuées sur cinq ans au moyen de séries chronologiques de la pluviométrie journalière sur autant d'années.

Le chapitre 11 présente et analyse les résultats des simulations réalisées au moyen du modèle BMM. Il comporte en particulier une analyse de sensibilité, avec une explication très claire des indicateurs choisis. Les résultats sont présentés sous la forme d'histogrammes en trois dimensions. Dans un premier temps, les simulations réalisées sur le terrain avec les agriculteurs afin d'explorer deux scénarios de leur choix sont décrites. Le premier scénario est caractérisé par l'absence de contrainte en force de travail agricole grâce à l'accès à de la main d'œuvre salariée saisonnière en provenance des pays voisins (Laos et Cambodge). Le second simule un meilleur accès à l'eau agricole au moyen de bassins individuels toujours remplis d'eau durant le cycle rizicole. Par rapport au scénario de base restituant les conditions actuelles, les résultats de simulation du premier montrent de plus grandes différences de revenus entre les types d'exploitations agricoles. Elles sont dues à des pertes d'opportunité d'emploi salarié agricole pour la main d'œuvre des plus petites exploitations ainsi qu'à de meilleures ventes de riz de haute qualité obtenus par des récoltes plus rapides sur les plus grandes exploitations. Le second scenario simulé souligne l'importance de disposer de bassins de stockage de l'eau pour pouvoir réaliser les repiquages du riz à temps chaque année, ainsi que la forte liaison entre abondance de la disponibilité et eau et emploi de la main d'œuvre sur les exploitations. En effet, sans contraintes hydriques, toutes les exploitations implantent leurs cultures au même moment. Les très intéressants commentaires des agriculteurs sur les résultats de ces scénarios simulés sont aussi restitués. Ces simulations participatives ont démontré la faisabilité de l'usage de tels outils pour le co-apprentissage entre chercheurs et riziculteurs à propos des dynamiques clés et motivantes du système socio-écologique.

Une analyse de sensibilité détaillée du modèle BMM et des simulations complémentaires ciblées sur l'interaction entre la disponibilité en eau et la gestion de la main d'œuvre ont été réalisées en laboratoire sont ensuite présentées. L'analyse de sensibilité explore l'influence des paramètres suivants : date du début de l'implantation des pépinières de riz, seuils de pluviométrie les déclenchant, niveaux d'eau initiaux dans les bassins de stockage de l'eau sur les exploitations, ainsi que les seuils de pluviométrie journalière permettant le début des repiquages.

Les résultats de la simulation de neuf scénarios faisant varier les disponibilités en eau (trois différents niveaux) et en force de travail (également selon trois modalités) sont ensuite analysés de façon comparative pour les quatre exploitations agricoles de type différents simulées au moyen des indicateurs suivants : revenus des ventes de paddy, salaires agricoles perçus, nombre de migrants. Ils montrent notamment que ce dernier indicateur est fortement influencé par le niveau de disponibilité en main d'œuvre salariée extérieure au village, mais finalement peu par le niveau de disponibilité en eau.

Le chapitre 12 fournit une évaluation qualitative réflexive des différents types d'effets découlant de la mise en œuvre de la modélisation d'accompagnement dans cette étude de cas sur les trois grands types d'exploitants agricoles participants. Les agriculteurs considèrent que le modèle co-produit représente suffisamment bien leurs pratiques de gestion rizicole et des migrations. Selon eux ce type d'échanges, stimulé par des exercices évolutifs de simulation, facilite efficacement l'intégration des connaissances de différentes sources. Il les rend aussi plus confiants et augmente leur capacité à faire face aux imprévus. Les autres types d'effets sur les individus documentés ont trait à l'apprentissage et l'acquisition de nouvelles connaissances à propos de la question examinée, aux changements de perceptions de soi-même et des autres, ainsi que de comportement, aux modes de communication et relations sociales, à la prise de décision et l'adoption de nouvelles pratiques. Le processus a surtout induit des apprentissages, mais de façon différenciée entre types de riziculteurs. Si les petites exploitations se sont plus intéressées aux dynamiques agricoles et de migrations de main d'œuvre, les plus grandes se focalisaient sur les processus économiques. Les participants ont aussi identifié une proposition commune pour la poursuite du processus centrée sur le thème de la diversification commerciale de la production végétale en relation avec la disponibilité en eau agricole.

Le dernier chapitre rassemble des éléments de discussion, de conclusion et de recommandation concernant surtout les aspects méthodologiques et de gestion de ce type de processus de modélisation collaborative. L'importance des activités préparatoires au lancement de processus ComMod y est soulignée, tout comme la nécessaire identification préalable de la question à traiter avec une diversité d'acteurs formulant le problème à examiner. Les modalités de sélection des participants (notamment pour leur capacité à s'impliquer réellement et à suivre de tels processus) et d'évolution du groupe sont aussi abordées. Des réflexions sur les points forts et les faiblesses des deux grands types d'outils mobilisés, jeux de rôles et modèle multi-agent informatique, sont également fournies, notamment en terme de coûts et bénéfices, mais aussi à propos de leur appropriation par les acteurs et de leurs usages futurs, tout comme au sujet de l'intérêt d'une abstraction croissante des visualisations.

CHAPTER 1
INTRODUCTION

Lord Curzon in 1890 stated "It is a gamble on the monsoon", a famous statement referring to the rainfed agricultural situation in India. That statement could very well be applied to farming conditions in Northeast Thailand. Moreover, such a gamble becomes more complex because it interplays with more socio-economic dynamics. This chapter introduces brief characteristics of the study site at regional and community levels. The justification for conducting this research is provided followed by the research problem and objectives. The methodology used is also briefly presented followed by the expected outcomes.

1.1. Background Information and Resource Management Problem

Northeast Thailand is mainly a large plateau on sandstone, called "Isaan", which is usually characterized by poor soils and under the influence of the erratic monsoon rainfall. It covers one third of the Kingdom's area and contains a third of its total population. Northeast Thailand's 20 million inhabitants mainly belong to the Lao and Khmer (in the southern part) ethnic groups. The Isaan region is also, by far, the poorest of the country and is still a major rainfed lowland rice (RLR) growing area on millions of hectares (Jongdee, Pantuwan et al., 2006; National Economic and Social Development Board, 2003; Office of Agricultural Economics, 2007). The severe agro-ecological constraints cause low paddy yields with an average of some 1.8 t ha^{-1} (Somrith, 1997). Two sub-regions can be distinguished: the Chi and Kong Basins in the upper part and the Mun Basin in the lower northeast. The upper northeast is characterized by an undulating topography favouring the adoption of important industrial cash crops such as kenaf, cassava and sugarcane. In the more monotonous lower northeast, the agricultural diversification out of rice is still far more limited. Although the famous aromatic jasmine rice (KDML105) is largely grown, its higher commercial value cannot compensate the low farm productivity (Office of Agricultural Economics, 2007).

Past agricultural research and development efforts emphasized agricultural intensification by alleviating the risk of drought and improving soil fertility but their impact has been limited. Particularly, when water availability has been improved by governmental agencies, farmers have not taken this opportunity to intensify their production practices as expected (The World Commission on Dams, 2000). In this context and in most cases, agricultural production is not sufficient enough to satisfy local households' economic needs in this relatively poor part of the Kingdom (average monthly household income is about 8,800 baht (190 euro) as reported by the National Statistical Office of Thailand, 2007). Many people in the 20 to 35 year old age bracket consistently migrate to search for more profitable off-farm employment in industrial and urban areas; the Northeast provides the largest proportion of out-migrants nationwide as more than a third of all interregional migration originates from this region (Santiphop, 2000).

Labour migration, particularly working abroad, is regarded by migrants as a strategy of life support and is sometimes life-enhancing (Jones and Pardthaisong, 1999). Remittances from migrant workers are also a key factor in reducing income disparity among regions. However, labour migration from farm to non-farm sectors is an increasingly important issue in Thailand as farm labour scarcity affects many social and technical changes in the agricultural sector (Shinawatra and Pitackwong, 1996). At the same time, the King of Thailand's concept of sufficiency economy, and its application in agriculture through the "New Theory" advocating the adoption of integrated agricultural production systems, is being promoted among local farmers to improve food security and secure a decent quality of life at the farming household level. In particular, these development efforts have led to the digging of thousands of small farm ponds in the paddies of Issan during the last 15 years (Jitsanguan, 2001).

The Lam Dome Yai watershed where the study site is located, is the largest watershed in southern Ubon Ratchathani province, lower northeast Thailand. The Lam Dome Yai River merges into the Mun River flowing eastwards to join the Mekong River at the Thai-Lao PDR border. The social-agroecological system (SAES) of this watershed is characterized as an RLR ecosystem in a drought-prone (and in some parts flood-prone) area allowing only one low yielding rice crop cycle per year. The majority of RLR growers are small and resource-poor farmers with very limited access to irrigation water, and their farm management still relies heavily on human labour. Various strategies – such as diversification into annual, or more recently perennial, cash crops – have been used by community members to increase their agricultural output and secure adequate household incomes. However, for many of these small holders, labour migration has been perceived to be the most successful choice for attaining their economic goals, even if they have to leave their land and water underused and put their children in the care of elderly people at home in the dry season. Once some family workers move out, the household needs to adapt its farming strategy and practices to deal with family labour scarcity. For instance, more labour-intensive farm activities are either abandoned or downsized.

The influential Royal Irrigation Department (RID) has attempted to implement a controversial project to build a new dam on the Lam Dome Yai River to increase irrigated areas in this watershed. Like in other areas of the Northeast region of Thailand, it was observed that similar costly investment and centrally controlled water storage and distribution infrastructures were inadequate in meeting local farmers' needs, and faced maintenance problems leading to even lower efficiency (Chantawong, Boonkrob et al., 2003). The suitability of such top-down water improvement schemes is also questionable as they usually do not work well with small farmers' socio-economic strategies, especially regarding labour mobility. Therefore, an important assumption of my research team was that a similar costly failure could occur in the Lam Dome Yai watershed if a better understanding of the interaction between land/water use and labour mobility/migrations was not achieved and taken into account by policy makers at this stage. Prior to the implementation of development project, a common understanding of such interaction is necessary to be created among the most concerned stakeholders, in particular the main group of end users: the local farmers. Besides, stakeholder involvement is promoted at the national level under the decentralization of the management of local resources policy (Charoensutipun, 2001). Several local administrative bodies (like the now powerful and well-funded Tambon Administrative Organization-TAO[1]), and government agencies (like the Community Development Department-CDD, under the Ministry of Interior which is responsible for the promotion and development of community organization, leadership and networks for poverty eradication and local development) are active. Consequently, it was decided that a collaborative modelling process based

[1] One 'tambon' or sub-district is made of 10-12 villages.

on the Companion Modelling (ComMod) approach would be launched to investigate this key interaction in the central part of the watershed.

Based on the ComMod approach, in this research, a particular aspect to be examined through an innovative co-design and co-construction of models with local farmers is the interaction between land/water use and labour migrations. In this experiment, the diversity of decision-making process about farm management belonging to heterogeneous stakeholders plays a crucial role to building a shared representation of the system and issue under study. Such shared representation is presented by a family of models co-designed with local farmers. These models, then, is used to facilitate knowledge exchange and knowledge discovery through the participatory simulation exercises leading the local farmers to be more adaptive on their farm management. Through a series of knowledge sharing activities, both researchers and local farmers could gain better understanding of the current situation. More practical and acceptable alternative water development scenarios would possibly emerge during this collaborative modelling process.

The key renewable resource management problems in this study area are:

1. There is no effective methodological process to facilitate local farmers to build a common understanding about their resource management as a result of interaction between land/water use and labour migration. A poor understanding of this interaction could lead to the failure of costly state-funded development of new water infrastructures.
2. Local farmers have limited knowledge regarding the current situation and consequences of such interaction.

The related research questions are:

1. Can local farmers engage in the collaborative modelling process to co-design and co-construct models representing their system?
2. Can a shared representation of the system regarding issue being examined be build among participants through knowledge sharing activities during the collaborative modelling process?

3. Is it possible to use co-designed models to support co-learning process and integrate scientific and indigenous knowledge between scientists and the local farmers with primary education level?
4. Can local farmers use the co-designed models to express and exchange their perceptions, and collectively explore their interesting scenarios?
5. What are the effects of the collaborative modelling process on farmers' farm management and labour migration practices?

1.2. Research Objectives

The main research objectives were as follows:

1. To improve the understanding of the interactions between land/water use and labour migration through the collaborative modelling process to co-design and use a family of models.
2. To offer tools and a methodology that enhances the capacity of expression of the different stakeholders, to facilitate their collective assessment of the problem at stake, and to improve their coordination through the collective identification, simulation and assessment of scenarios of change.

To accomplish these main objectives, specific objectives were defined as follows:

1. To understand the recent land use and cover change in the study area and the driving factors of such changes.
2. To categorize the local household-based agricultural production systems (APS) to elucidate their respective strategic decision-making processes regarding farm management and labour migration practices across types.
3. To design a conceptual model representing the structure and interactions of the components of the system under study to be taken into account.
4. To implement Role-Playing Games (RPG) and an Agent-Based Model (ABM) based on this gradually improved conceptual model.
5. To organize participatory simulation workshops using associated RPG and ABM tools to share knowledge and establish a shared understanding of the problem among stakeholders, and to enrich and validate the conceptual model.

6. To identify and explore future scenarios with the concerned stakeholders and assess their simulated results by focusing on the co-adaptation and co-viability of stakeholders' land/water use, and labour migration.

1.3. Materials and Methods

1.3.1. Study site and participants

The Ban Mak Mai village is located in a sub-watershed of the central part of the Lam Dome Yai watershed and represents a typical RLR-producing area found across the lower northeast Thailand. 21 local rice farmers belonging to 11 diverse farming households of this village were recruited to join this research to cover all main farm types based on a typology of the local farming households built during the initial diagnostic phase.

1.3.2. Methodology

Collaborative modelling refers to group model building with active involvement of model users in the modelling process. It is a promising approach that enables a better understanding of complex issues through the exchange and integration of knowledge derived from different disciplines and experiences (Eden and Ackermann, 1996). A shared understanding and representation of the problem at stake built among participating stakeholders during the process can result in improved collective resource management, and adaptive management capacity (Ashby, 2003; Narayan, 1996; Selener, 1997). Companion Modelling (ComMod) is a very interactive modelling approach involving the collaboration of stakeholders throughout model design and its use. This approach refers to a dynamic perception of the decision-making process in which the scientific and technical perception is only one point of view among others, and not the pre-supposed right perception toward which the decision should be attracted (Barreteau, 2003b). ComMod aims to develop a series of models that integrate stakeholders' representations and knowledge by encouraging stakeholders' participation throughout the process so that their adaptive capacity increases. It emphasizes better understanding of interactions between ecological and socioeconomic dynamics.

ComMod is based on continuous and iterative back and forth phases between the laboratory (model implementation), and field activities (interviews, specific field surveys, and/or participatory modelling and simulation workshops) generating a succession of evolving loops. The decision-making process of stakeholders is considered as essential to understand interactions among stakeholders whose objectives, perceptions, kind of information and representations are different (Bousquet and Trébuil, 2005). An important concept of the ComMod approach is Multi-Agent Systems (MAS), which originated in the field of computer science (Distributed Artificial Intelligence: DAI) and social science (Artificial Life). It is a promising concept that allows researchers to represent complex systems. MAS is based on the idea that it is possible to represent the behaviour of entities active in a common world in computerized form, and that it is possible to represent a collective phenomenon as the outcome of the interactions among an assembly of individual agents with their own operational autonomy (Ferber, 1999). Models produced through ComMod processes, therefore, reflect the MAS concept. ComMod models support co-learning in areas where the researcher is a stakeholder among other stakeholders in the system. An original characteristic of the ComMod methodology is the flexible association of key tools such as RPG and ABM, and also geographic information system (GIS), surveys and interviews (Bousquet et al., 2005).

In this case study, ComMod is used to develop a comprehensive model with stakeholders regarding interactions between rice farm management and labour migration practices in lower northeast Thailand through a collective learning platform and a series of participatory workshops. This ComMod process focuses on knowledge exchange among stakeholders, including the research team, to create a shared representation of the system through the development of a co-designed ABM. The ABM is, then, used by stakeholders to explore possible future scenarios of change. Moreover, with this platform, stakeholders' adaptive capacity could also improve.

1.3.2.1. Initial Diagnosis Activities

This research phase identifies the system under study (e.g. literature review, GIS operations, field surveys, and agricultural system analysis) in order to produce the necessary field-based knowledge. For the climatic analysis, rainwater volume and its distribution still play a crucial role in determining the level of agricultural yields, especially in the RLR ecosystem. But rainfall distribution in this area is very erratic and farmers have to adapt their cropping calendar to current field conditions such as soil moisture and water resource accessibility. The local climate is analyzed by using 50-year meteorological data (1953-2003) from the northeast meteorological centre. The frequential analysis of rainfall distribution is used to illustrate the highly variable and unpredictable characteristics of the local climate (See chapter 2 for more details). To analyze land use and cover change (LUCC) and to understand the causes of such changes, spatial and temporal analysis of remote-sensed (RS) data and Geographic Information System (GIS) operations are carried out. Satellite imagery, aerial photographs, and topographic maps are acquired from various sources. RS and GIS operations are processed to explicitly display the spatial changes of three successive periods (see details in chapter 3).

The current landscape and land use is an historical product of the past relationship between farmers and their environment. This must be understood to assess the initial situation at the beginning of the research. The household-based APS refers to the whole structured set of plants, animals and other activities selected by a farmer for his production unit to achieve his objectives. The APS is finalized by a farmer's socioeconomic objectives and related management strategy. APS typology identifies the different types of farmers by looking at their respective interests, means of production, social relations, and behaviour towards technological evolution. It is assumed that different types of farmers pursuing different socio-economic objectives by implementing different strategies exist and that they have access to different amounts of land, labour and capital resources. The purpose of using APS analysis is to examine the diversity of decision-making processes among these heterogeneous groups of farmers regarding the problem under study. Field surveys with semi-structured interviews are carried out to acquire complementary information about the relationship between production combinations (farm and non-farm activities) and labour migration (see chapter 5 for more details). The elicited farmers' decision-making processes are later used to conceptualize the behaviour of rule-based agents in the ABM.

1.3.2.2. ComMod Process

The outputs of the preliminary system analysis are used for the model formalization. The conceptual model is formalized in the Unified Modelling Language (UML) to represent decision-making processes of stakeholders as well as the structure and the relationship of components existing in the system under study. The conceptual model is also used as a mediation tool for knowledge sharing among different experts. Another use of the conceptual model is to design RPGs and an ABM. From this point, the continuous and iterative ComMod cycles begin to develop a shared representation between stakeholders through the collaborative modelling process (see chapter 8 for more details).

First, the initial conceptual model is transformed into RPGs (see chapter 9 for more details). The RPGs facilitated by the researcher are played by stakeholders through series of participatory modelling workshops. The results derived from RPG sessions are used to enrich the initial conceptual model, which is transformed into an ABM prototype. The ABM is built under the CORMAS[2] (COmmon-pool Resources Multi-Agent Systems) platform, which is a programming environment dedicated to the creation of a MAS with a focus on natural resource management. Subsequently, the family of ABMs is co-constructed through a series of short participatory simulation workshops, and the final version of the ABM is used by local rice farmers to explore possible future scenarios (see chapter 10 for more details). The simulated results are used for further analysis to better understand the system under study or formalize new questions and hypotheses (see chapter 11 for more details).

1.4. Expected Outcomes

The outcomes expected from this research are as follows:

1. The research team and other concerned stakeholders would have better understanding of the current situation regarding the interactions between land/water and labour migration through the knowledge sharing activities during the collaborative modelling process.
2. Since RPGs are relatively simple and represent the system where participating farmers live and work, the participating farmers should be at ease when

[2] CORMAS is being developed at CIRAD (http://cormas.cirad.fr/indexeng.htm) in Montpellier, France, and is based on the Smalltalk object-oriented language.

playing it and their decision-making processes could be revealed during the gaming sessions.

3. The ABM could be a powerful tool to integrate knowledge from diverse sources and engage the participating farmers in the virtual environment to build a shared representation and explore scenarios of interest.
4. The stakeholders’ knowledge of the defined problem can be improved through the co-learning process occurring throughout the participatory modelling activities.
5. The stakeholders’ adaptive capacity could be increased, helping them become more resilient and better prepared to face external shocks.

The dissertation comprises three parts and: (i) Agrarian characteristics of lower northeast Thailand (four chapters), (ii) Companion Modelling (ComMod) to understand the interaction between land & water use, and labour migration (three chapters), and (iii) Results (four chapters). The introduction, and conclusion, discussion and recommendations are presented separately in chapters 1 and 13 respectively.

Chapter 2 presents the dynamics of the agrarian system in the lower northeast region. The biophysical and socioeconomic characteristics of the northeast region influencing the current regional context are compared to other regions. The characteristics of the study area include: the evolution of transportation networks; APS and land use change based on interpreted findings from farm surveys, and the analysis of secondary data using GIS and RS presented in chapter 3. A review of the literature regarding labour migration in Thailand is provided in chapter 4 with an emphasis on migration decision-making processes. Chapter 5 presents a synthesis on the diversity of APS based on the integration of three successive farm surveys carried out in the study area. Based on the comparison and identification of similarities and differences between various APS, several main types of farmers are defined in a typology.

Chapter 6 presents the collaborative modelling approach illustrated by the analysis of six collaborative models. The highly interactive collaborative Companion modelling (ComMod) approach and methodology and its underlying theories are presented in chapter 7. Chapter 8 deals with the ComMod process implemented in Lam Dome Yai watershed, including details on the participants. Detailed information on the process design and its implementation, as well as the recapitulation of the evolving modelling tools over the whole process is also provided in this chapter. Three RPGs and the Ban Mak Mai (BMM) Agent-Based Model implemented in this experiment are described in chapter 9 and 10 respectively. Chapter 11 presents the explorations of scenarios carried out by running the BMM simulations during participatory simulations with RLR farmers and in the laboratory. The assessment of ComMod's effects on participating farmers is presented in chapter 12, followed by the conclusion, discussion and recommendations in chapter 13.

PART 1 AGRARIAN CHARACTERISTICS IN LOWER NORTHEAST THAILAND

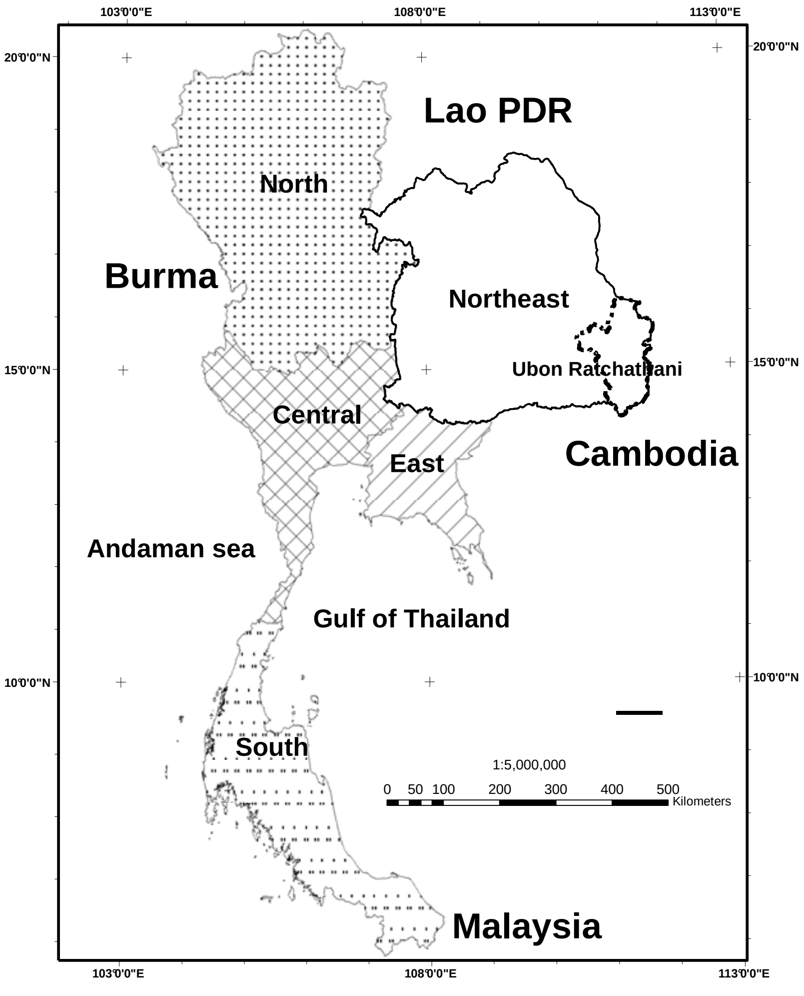
CHAPTER 2
AGRARIAN SYSTEM IN LOWER NORTHEAST THAILAND

In Thailand, agriculture, particularly rice production, is a backbone economic sector; in fact, Thailand is the world's largest rice exporter. 20% of farm land is categorized as rice-producing area (Office of Agricultural Economics, 2007). The northeast, the largest region both in terms of area and population, contributes an extensive share of land and labour to agricultural production. The evolution of this large agricultural based region has been influenced by ecological changes, economic incentives, and technological and infrastructure improvements leading to the emergence of various regional agrarian systems. An agrarian system is defined as a historically constituted mode of exploitation of the environment, durably adapted to the bioclimatic conditions of a given area and corresponding to the social conditions and needs at that moment.

Because the current agricultural landscape and land use is an historical product driven by past interactions between socioeconomic changes and agroecological dynamics, this evolving process must be understood to assess the initial situation at the beginning of the research. In this chapter, the dynamics of the agrarian system in the lower northeast region is presented to provide knowledge on these interactions at national, regional and provincial levels. General characteristics of the northeast, or "Issan", region regarding land utilization, and demographic and economic dimensions are also compared to other regions to highlight its specific nature. The socioeconomic and biophysical settings are specifically addressed to state the importance of these foundations influencing the current regional looks. The rice ecosystem, the dominant use of land in this region, is further described. The chapter closes with a presentation of recent agricultural transformations and land use change at the provincial level.

2.1. The Northeast Region of Thailand

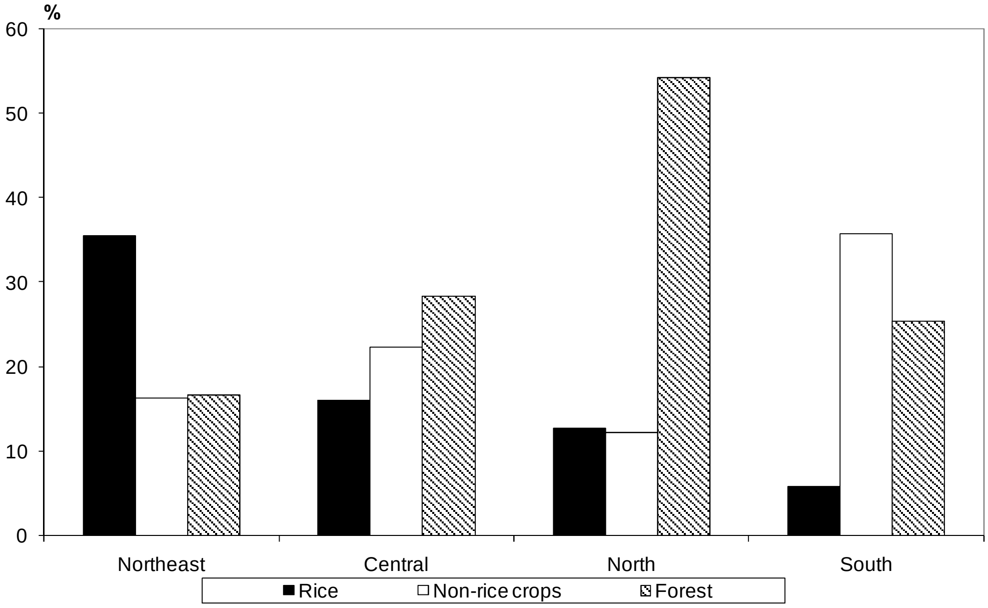
The Kingdom of Thailand has been known as the "Golden Land", in recognition of the high productivity of its farm lands and forests that benefit from the southwest wet monsoon from April to October. Based on geographic diversification, Thailand is divided into five regions: North, South, Central plain, East and Northeast (Figure 2.1). However, when the socioeconomic and demographic dimension is referred, the East is often considered a part of the Central plain. The northeast is the largest plateau in Southeast Asia (Mackill, Coffma et al., 1996). Lao PDR borders the north and east, and Cambodia borders the south, covering one third of the 513, 000 km^2 country size.



Source: Thailand on a disc 1996, Thailand Environment Institute (TEI).

Figure 2.1 Map of Thailand displaying five regions and its neighbouring countries.

This region is the largest rice producing area counting for 35% of total rice production land in Thailand with a small portion of forest cover compared to other regions (Figure 2.2). Rice producing area is preferably cultivated in large undulating shallow depressions, while non-rice crops such as cassava, kenaf and sugarcane are found in upland areas. A few dense tropical forests are conserved as national parks, located in the mountain range in the west, and in areas along the international border between Thailand and neighbouring countries, including the southern and southeastern regions of Ubon Ratchathani province.



Source: Agricultural Statistics of Thailand, Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.2 Percent of rice, non-rice crops, and forest areas by region, Thailand (2005).

In 2005, Thailand's population was estimated at 65 million making it the nineteenth populous country in the world (Library of Congress, 2007). Demographic records from the National Statistics Office show the estimates of Thailand's age structure in 2005. 23.9% of inhabitants are less than 15 years old, 68.6% are 15-64 years old, and 7.5% are 65 and older. Thai society is generally considered to be fairly homogeneous; 80% of the population is Thai, including related Thai ethnic groups such as Thai-Lao (Laotian) and Thai-Khmer. Another 10% are ethnic Chinese, and 3% are Malay, leaving 7% uncategorized. The largest share of the population resides in the northeast region with over 21 million inhabitants and a population density of 126 persons per square kilometer (Table 2.1).

Table 2.1 Population, density and households from registration census by regions, Thailand (2005).

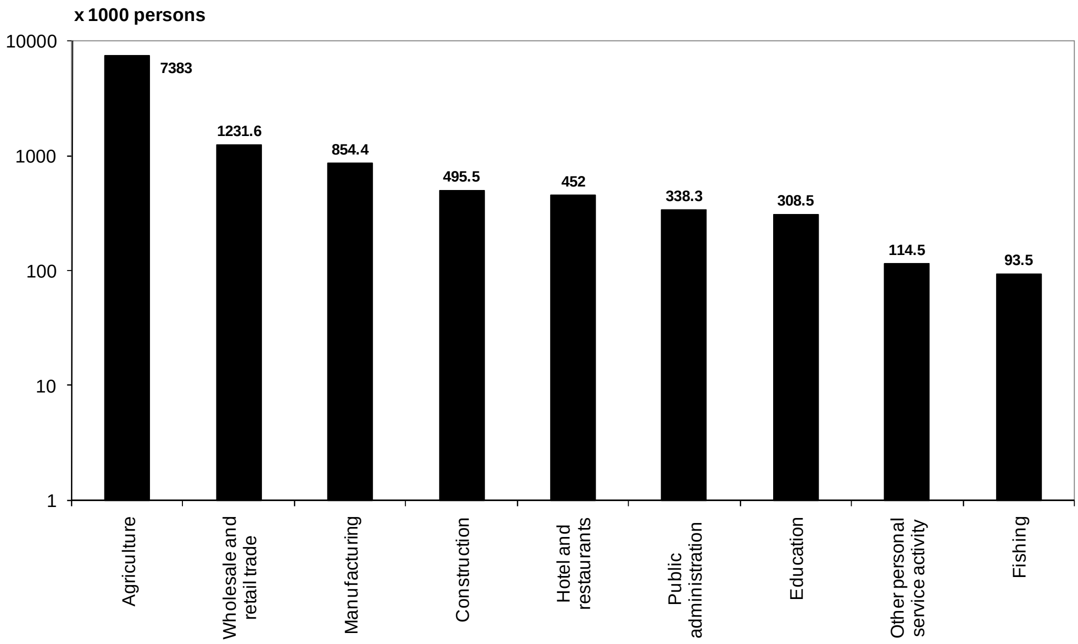
Region	*Population (x1000)*			*Area (km^2)*	*Density per km^2*	*Number of household (x1000)*
	Total	*Male*	*Female*			
Northeast	21,328	10,647	10,681	168,855	126	5,350
Central	15,031	7,368	7,663	102,336	147	5,322
North	11,884	5,879	6,005	169,644	70	3,768
South	8,517	4,219	4,298	70,715	120	2,485
Bangkok	5,659	2,706	2,953	1,569	3,607	2,092
Whole Kingdom	62,418	30,819	31,599	513,120	122	19,017

Source: http://www.nso.go.th/eng/pub/keystat/key03/Chapter1.xls Department of Local Administration, Ministry of Interior, Bangkok.

The agricultural sector occupying the largest share of farm land in the northeast is managed by about 7.4 million northeasterners (Figure 2.3). However, the revenue generated by this sector is not enough to reduce the level of regional poverty as shown by the decrease of Gross Domestic Product (GDP) in the farming sector (Figure 2.4). As indicated by high incidences of poverty, the northeast remains the all-time poorest region in the kingdom (Figure 2.5). More details on this topic are provided below.

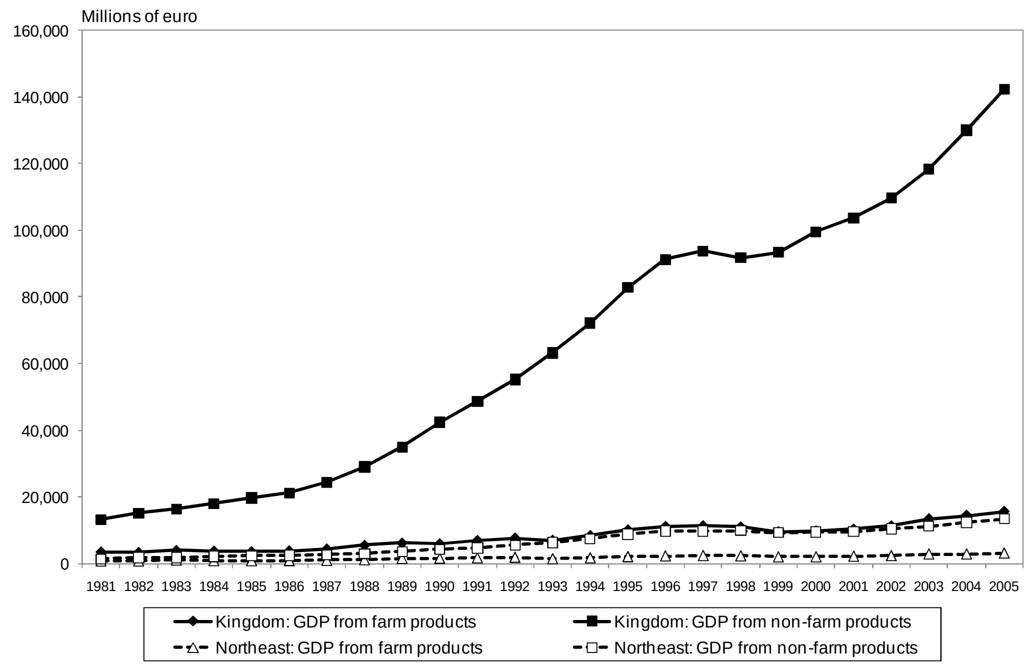
Regarding the regional demographic characteristics, the number of out-migrants is relatively high compared to other regions. This region contributed more than a third of all interregional migration in 2005 (Figure 2.6). Much of these out-migrants travelled to Bangkok and its periphery to work in industrial and service sectors. (Matsumura, Isarabhakdi et al., 2003). The flow of labour migration can be considered as a common response to the regional poverty as rural households look for additional cash income to help meet their basic needs.

To understand the high rate of poverty in this large agricultural-based economy that in turn leads to a high migration rate, it is essential to look at the regional socioeconomic characteristics in relation to poverty.



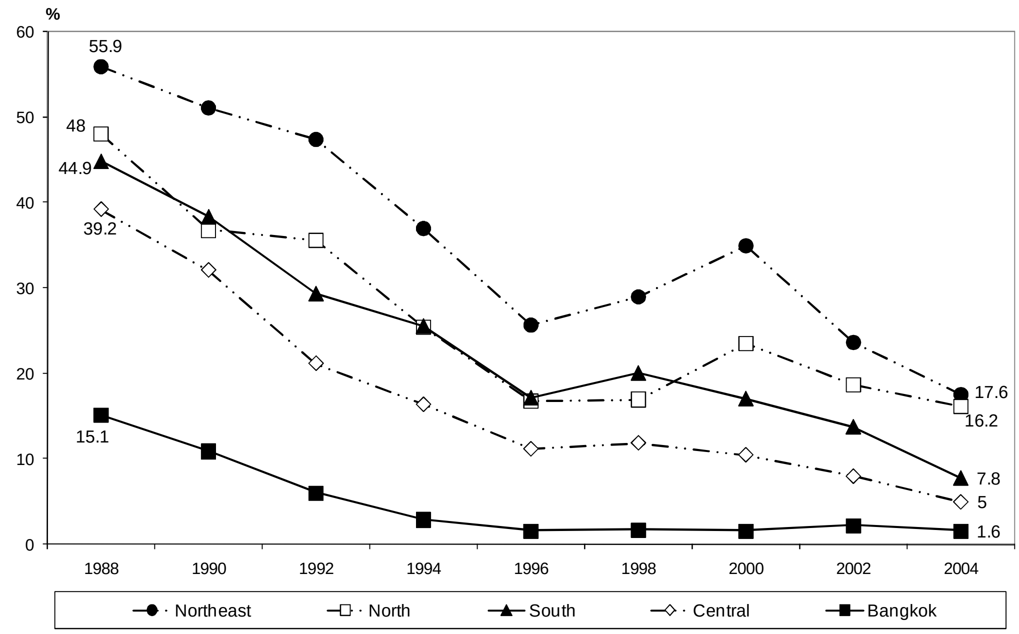
Source: Labour Force Survey Quarter 4/2005, National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

Figure 2.3 Number of workers employed by economic sectors in northeast Thailand (2005).



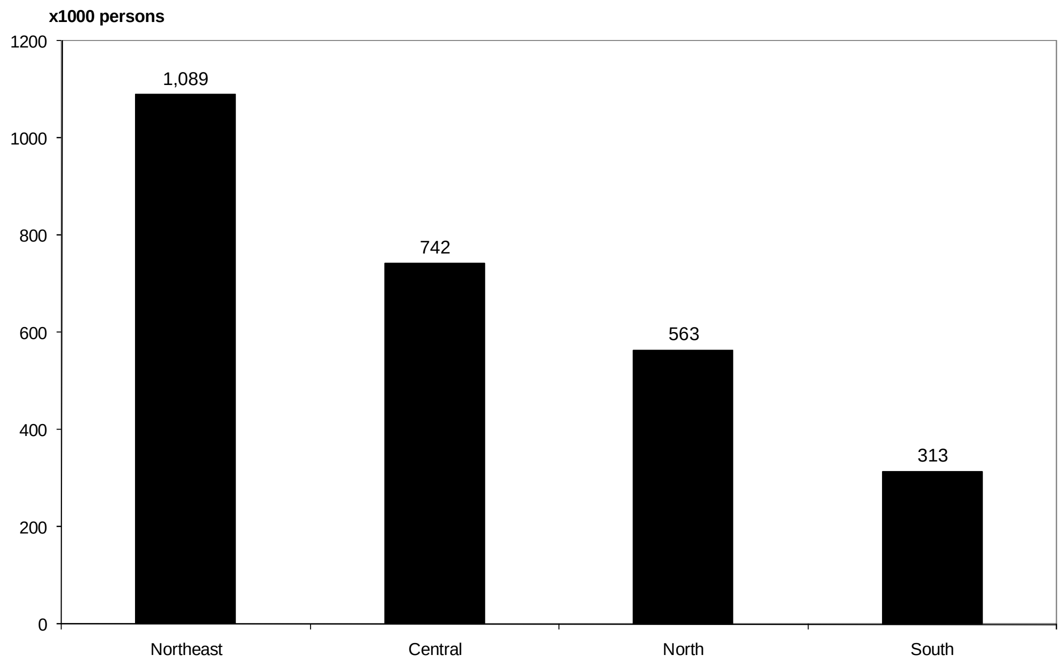
Source: Gross Domestic Product of Thailand 1980-2001 and 2005 edition, Office of The National Economic and Social Development Board (NESDB), Office of the Prime Minister, Bangkok.

Figure 2.4 Evolution of Gross Domestic Product (GDP) generated by farm and non-farm sectors at national and regional level (1981-2005).



Source: Statistic Year Book 2006, National Statistical Office, Ministry of Information and Communication Technology, Bangkok.
Note: Thailand measures poverty incidence at household level by comparing per capita household income against poverty line which is the income level that is sufficient for an individual to enjoy the society's minimum standard of living.

Figure 2.5 Evolution of poverty incidence by region, Thailand (1988-2004).



Source: Department of Local Administration, Ministry of Interior, Bangkok.

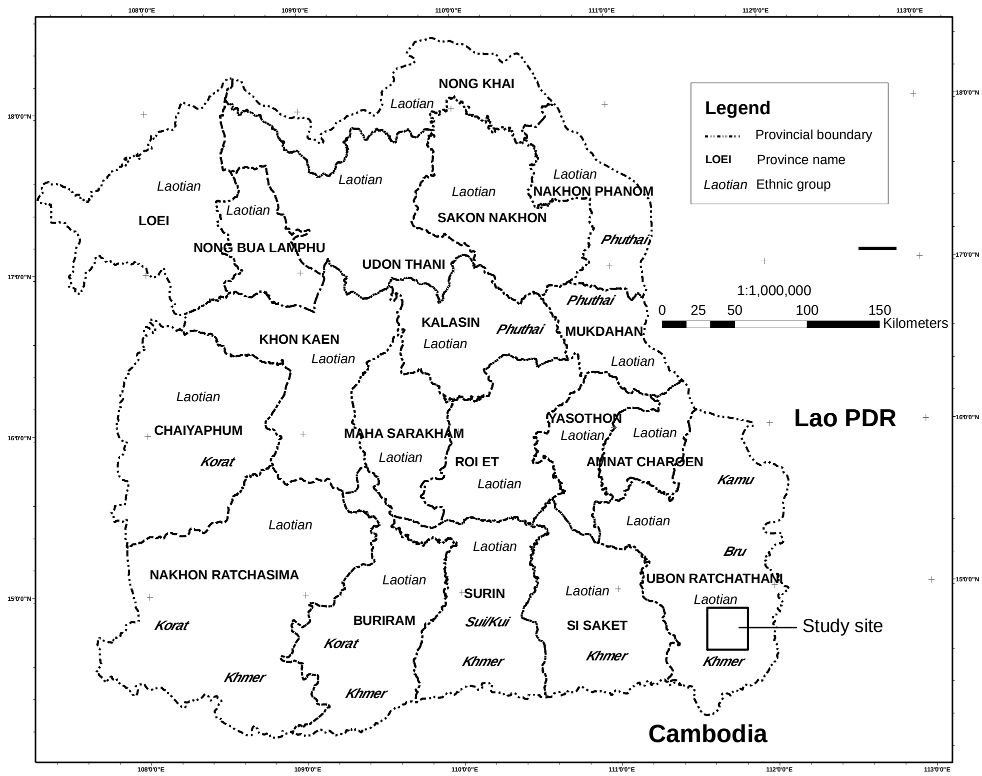
Figure 2.6 Number of out-migrants by region, Thailand (2005).

2.2. Socioeconomic Characteristics

The region's evolution has been based on agricultural and technological development interventions, influenced by the state's policies, markets, and human resource coming from a mix of diverse ethnic groups and cultures. The regional socioeconomic dynamics including demographic changes, economic transformations, and state policy implementations are all partly responsible for the emergence of persistent regional poverty among north-easterners.

2.2.1. Ethnic Groups and Evolution of Population Structure

The regional population is dominated by Thai-Lao ethnic rural dwellers concentrated in the provinces of Nakorn Ratchasima, Khon Kaen, Udon Thani and Ubon Ratchathani, while a significant minority of Khmer people lives in the southern part of the region, along the border with Cambodia (Figure 2.7).



Source: Adapted from northeast provincial boundary map, Geographic Information System Centre, Faculty of Engineer, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.7 Map displaying the distribution of ethnic groups throughout the northeast region of Thailand.

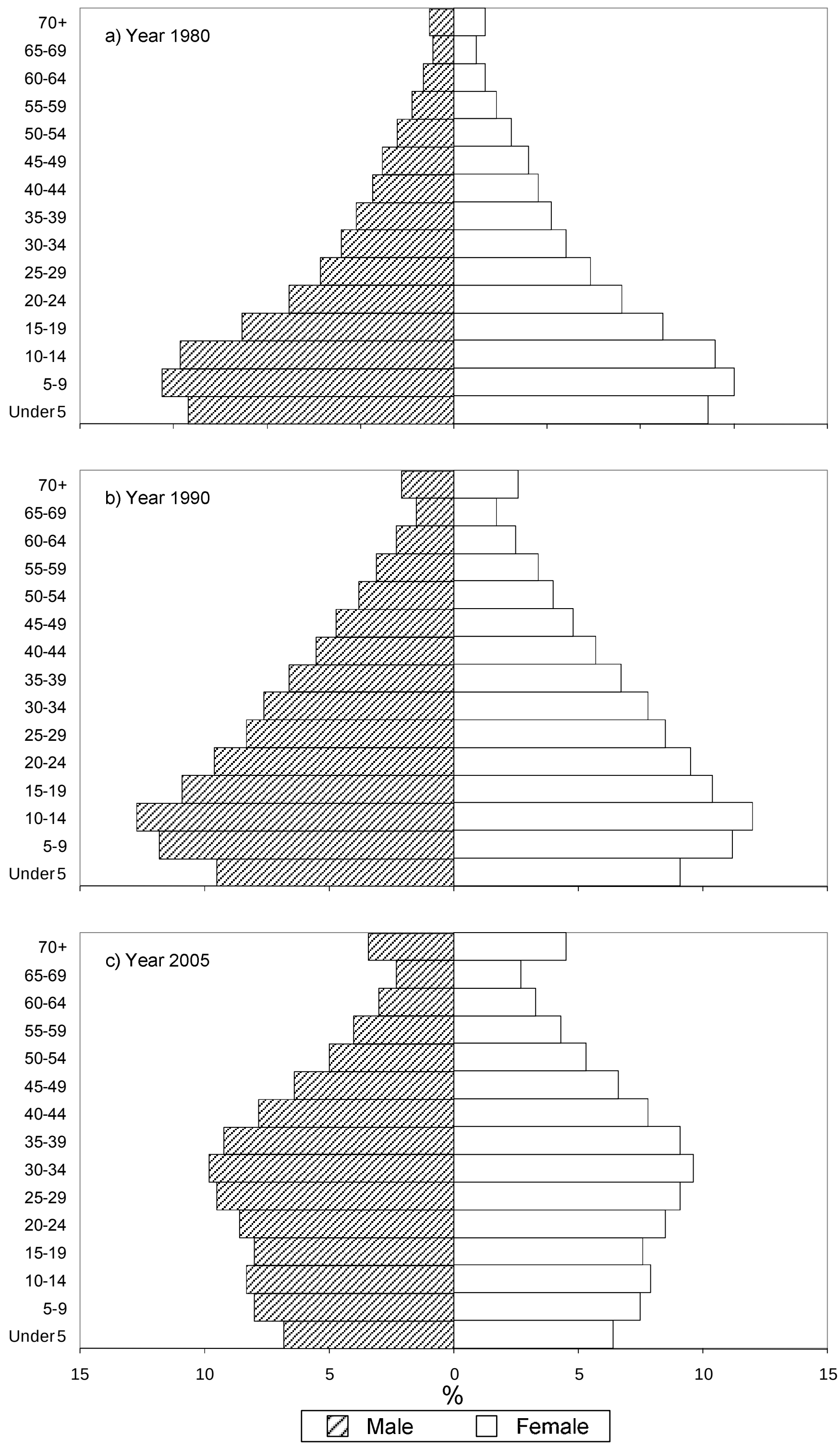
The culture and means of subsistence of the ethnic Lao is strongly linked RLR cultivation as indicated by the sequence of traditional festivals, along with rice-growing practices in villages (Faculty of Economics Kasetsart University, 2000). But, with regard to this cultural aspect, these ethnic Lao farmers are also well known to be adaptive and fast learners to new settlements. Therefore, they still make up a large share of interregional migration compared to other groups (Promjuy, Panvisit et al., 2003).

In 2005, the regional population structure consisted of 24% of inhabitants aged less than 15 years, and 8% aged older than 65 years. Compared to the population structure in 1960, the number of elderly increased while the number of inhabitants whose age was less than 15 years old decreased (Figure 2.8). This demographic transition is due to a successful family planning program launched at the national level by the Thai government in 1968 (Figure 2.9), and the improvement of public health as seen in the decrease of infant mortality (Table 2.2).

Population growth is now slow. As a consequence of this low natural rate and better health care leading to longer life expectancy (Table 2.3), the population structure is likely to contain a more elderly proportion of people and a lower proportion of working aged people. This could lead to serious labour shortages in the future.

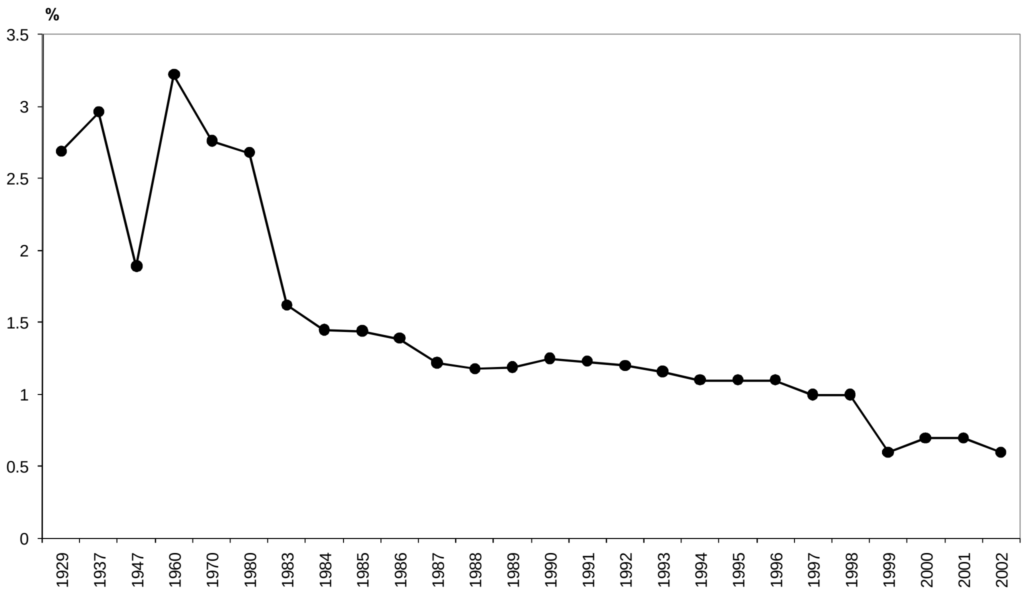
2.2.2. Evolution from Agricultural-based to More Export-led Economy and Poverty

Since the early 1960s, Thailand has experienced a pattern of economic development characterized by rapid growth in population, income, income per capita, and productivity. National economic reforms resulted in changes to Thailand’s former backbone economic sectors; Thailand’s economy moved from one based on agriculture and self-reliance to an economy led more by industry, service sectors and exports (Manarangsan, 2002). As a result of being more and more market-oriented, systems of rural self-subsistence declined and agricultural products became more vital in trading for cash. However, the benefits of Thailand’s recent economic growth are not equally distributed to all regions.



Source: a) Household Survey, Minister of Interior, Bangkok.
b) Thailand Population Census, Central Statistic Office, National Economic Development Board, Bangkok.
c) Health Information Unit, Bureau of Health Policy and Strategy, Ministry of Public Health, Bangkok.

Figure 2.8 Northeast population pyramids comprised of 5-year age groups for both sexes, Thailand (1980, 1990, 2005).



Sources: Public Health Statistic A.D. 1984, Bangkok (1929-1980).
Public Health Statistic A.D. 1993, Bangkok (1983-1991).
Public Health Statistic A.D. 2005, Bangkok (1992-2005).

Figure 2.9 Evolution of the rate of natural population increase, Thailand (1929-2002).

Table 2.2 Birth, death and infant morality rate in Thailand (1963-2005).

	Year					
Rate	*1963* [1]	*1975* [1]	*1991* [2]	*1995* [2]	*2000* [2]	*2005* [2]
Live birth [a]	35.7	28.4	17	16.2	12.5	13
Death [a]	8.2	5.9	4.7	5.5	5.9	6.4
Infant mortality [b]	37.9	26.3	8.3	7.2	6.2	7.6

Sources: [1] Statistic country profile for administrators, 1979, Bangkok.
[2] Health Information Unit, Bureau of Health Policy and Strategy, Bangkok.
Notes: [a] Live birth and death rates are number of live births and deaths per 1,000 populations.
[b] Infant mortality rates are number of infant death per 1,000 live births.

Table 2.3 Life expectancy in Thailand (1963-2005).

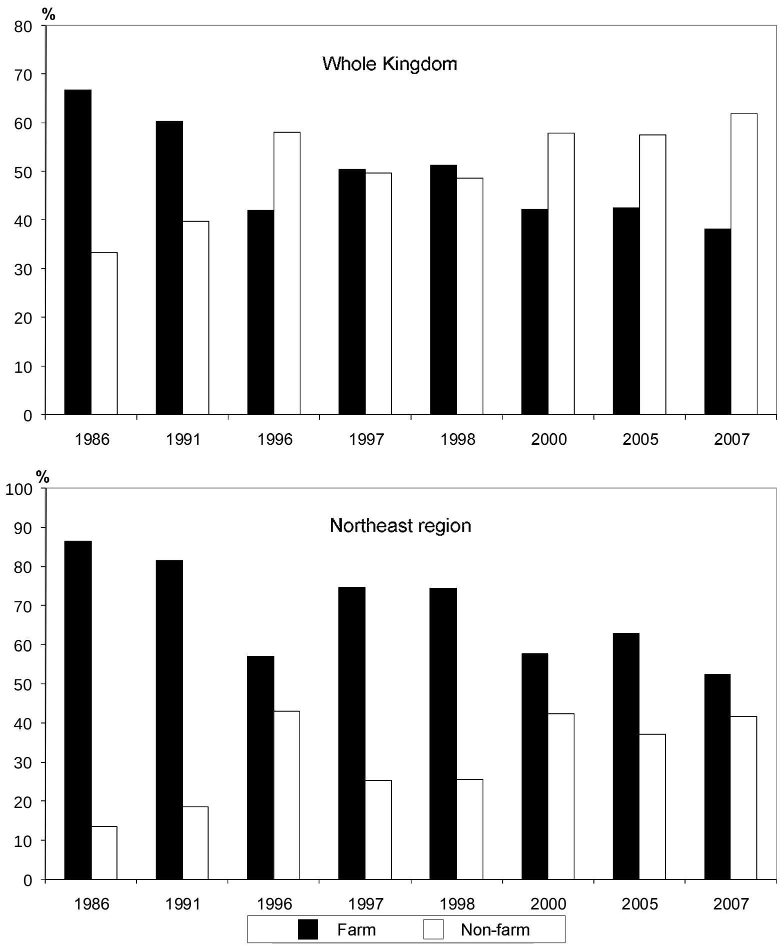
	Year					
Gender	*1963-1967* [1]	*1974-1975* [1]	*1985-1990* [2]	*1991-1995* [2]	*1996-2000* [2]	*2000-2005* [2]
Male	53.9	57.9	61.75	66.48	67.36	68.15
Female	58.6	63.6	67.5	71.04	71.74	72.39

Sources: [1] Statistic country profile for administrators, 1979, Bangkok.
[2] Health Information Unit, Bureau of Health Policy and Strategy, Bangkok.

During Thailand's economic boom in 1986-96, the northeast's farming sector produced a decreased share of GDP, while GDP of the non-farm sectors increased (Figure 2.4). There was also a flux of workers moving from the farming sector to the non-farming sector. In the northeast, 88% of the labour force worked on the farm in

1991; this share decreased sharply to 56% in 1996 (Figure 2.10). This type of labour transference shows a serious problem regarding income disparity among regions in relation to industrial and service sectors.

In June 1997, Thailand's economic bust caused a sudden increase in unemployment and new workers could not enter the market. The crisis affected people in rural areas because most of the households depended more and more on off-farm incomes. The economic crisis also caused hundreds of thousands of migrants to return to their rural homes after losing their jobs, and many reverse migrants returned to the northeast region (Subhadhira, Simaraks et al., 2004). Workers in the farm sector increased in 1997 while the number of non-farm workers decreased (Figure 2.10).



Source: The Labour Force Survey, National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

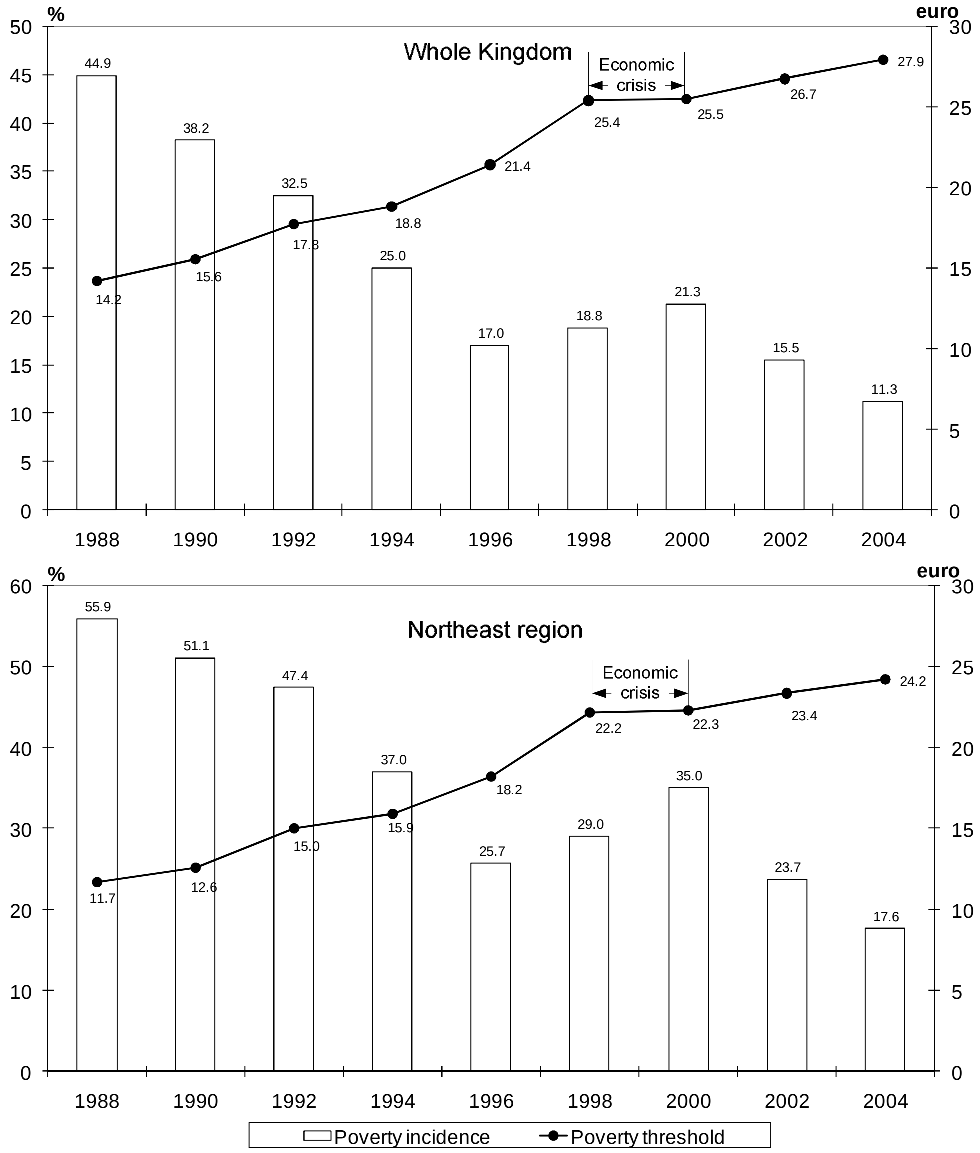
Figure 2.10 Labour force changes in the farm and non-farm sectors in Thailand and the northeast region (1986-2007).

However, in 2000, the portion of labour between the two sectors was similar to the situation in 1996 since the Thai economy had partially recovered. This indicates the tight link between economic growth and labour migration because the northeast people need to find more profitable employment than agriculture to increase household income.

Regional poverty has long been a problematic issue as indicated by longstanding high rates of labour migration (Feeny, 2003). Half a century ago, the great majority of Thai citizens were in poverty. However, during the past decades, economic development in Thailand has been successful in alleviating the incidence of absolute poverty; this reduction is defined as the gradual decrease in the number of people whose income lies below the poverty line (Na Ranong, 2000). In spite of the impressive achievement of poverty reduction, the numbers of poor in the northeast region, where one third of Thailand's population resides, is still high. In 2004, 17.6% of the northeast's population had a per capita income less than the official poverty line[3], compared to the national level of only 11.3% (Figure 2.11). This suggests that the northeast region has received limited benefits from the rapid economic growth. As defined in the national plan, around 40% of all the targeted poor villages at national level were located in the northeast region (See appendix 1).

This agriculture-based region is responsible for a large share in the export of rice, field crops, and tree plantations. According to the recent OAE report (2007) rice, sugarcane, cassava, maize, kenaf and Para rubber are listed as major economic plants in this region (Figure 2.12). However, sugarcane and maize are rarely produced in the lower northeast because the low-lying landform is less favourable for these crops. Household income commonly comes from the sale of rice and cassava. Para rubber plantations are increasing in response to its high price in the market. But this plant has limitations due to its high investment (availability of land and cash) costs, and long growth (7 years) harvesting cycle. Only better-off farmers can afford to grow it.

[3] The official poverty line of Thailand in 2004 was 1,300 baht (28 euro) per head per month assessed by the National Economic and Social Development Board (NESDB), Bangkok.

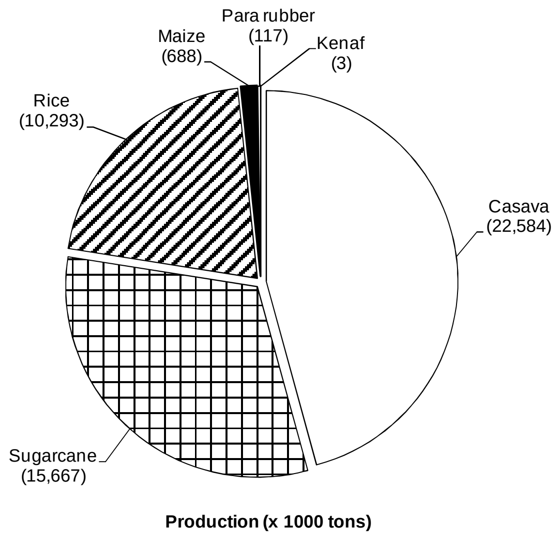


Source: Socioeconomic Survey, National Statistical Office, complied by National Economic and Social Development Board (NESDB), Bangkok.

Figure 2.11 Evolution of poverty incidences and official poverty thresholds (1988-2004).

2.2.3. Household Characteristics and Sources of Income

As one fourth of the people in northeast Thailand are engaged in the low profit agricultural sector, a farm survey by the Office of Agricultural Economics (Office of Agricultural Economics, 2007) found that around 2.7 millions households were resource-poor farmers with an average size of land holding at 3.2 ha.



Source: Agricultural Statistics of Thailand, Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.12 Share of major crop and para rubber production in northeast Thailand (2006).

Rice, glutinous for Laotian and non-glutinous for Thai and Khmer ethnic groups, is a main staple cereal in the local household food systems but its production contributes only 17-20% of the total cash income. Apart from rice, the northeast region is also producing more and more industrial cash crops (cassava, sugarcane, maize) but this economic activity is limited in the lower northeast. Rice is produced on most small holdings to reduce household expenses. These resource-poor farmers often encounter insufficient cash flow to meet basic human needs and face very serious indebtedness (Table 2.4).

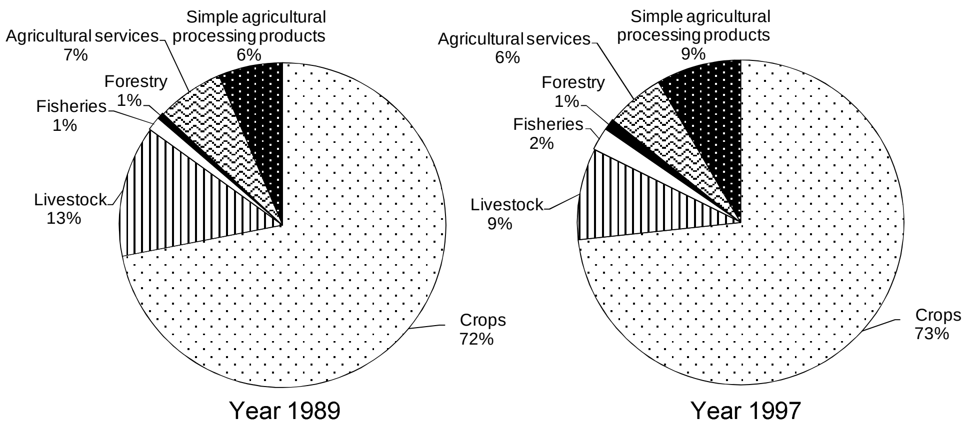
A common response to this unfavourable economic situation is labour migration in order to find more profitable employment in urban areas. Once some family workers move out, the household needs to adapt its farming strategy and practices to deal with family labour scarcity. More labour-intensive farm activities are either abandoned or downsized. Figure 2.13 shows that the share of labour-intensive livestock production decreased between 1989 and 1997.

Table 2.4 Recent average economic characteristics of farming households in northeast Thailand (2000-2004).

Household characteristics	*Year*		
	2000	*2002*	*2004*
Size	3.9	3.7	3.7
Farm holding size (ha)	3.6	3.5	3.4
Monthly income (euro)	173	206	225
Monthly expenditure (euro)	145	168	189
Amount of debt (euro)	1,167	1,467	1,851

Source: Statistic Year Book 2006, National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

The relative poverty of people living in the northeast can be considered as a result of the low profitability of the agricultural-based economy. Labour migration from this region plays a key role in alleviating poverty by securing more income from the non-farm sectors. The expected higher income at a receiving region such as Bangkok is seen as a major pull factor. Based on neoclassical economic theory, the key push factor driving resource-poor farmers to migrate are unfavourable environmental conditions at the sending region. In the case of this large agricultural-based region, it always refers to low agricultural productivity as a result of unfavourable agroecological conditions.



Source: Office of the National Economic and Social Development Board (NESDB), Office of the Prime Minister, Bangkok.

Figure 2.13 Recent changes in composition of the Gross Domestic Product (GDP) from the northeast's farm sector[4].

[4] Updated data are available but the sub-categories of farm sector are grouped into two types; 1) agriculture, hunting and forestry, and 2) fishery, which cause difficulty when comparison was carried out by using data surveyed before 1997.

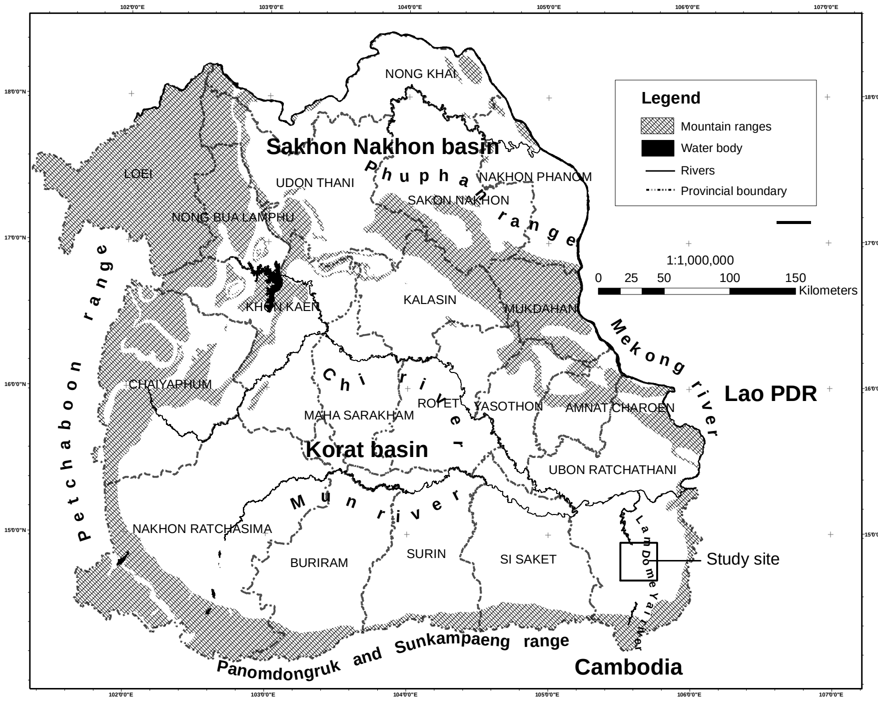
2.3. Biophysical Settings

The northeast biophysical conditions are an important cause of low agricultural productivity. The climate and soil constraints, the limitations of irrigation systems, and the improvement of transportation all influence the current characteristics of land and water resources in the region. This section presents these components of the regional biophysical system in relation to low farm productivity leading to high poverty rates at regional level.

2.3.1. Geology, Geomorphology, Landform and Soil Conditions

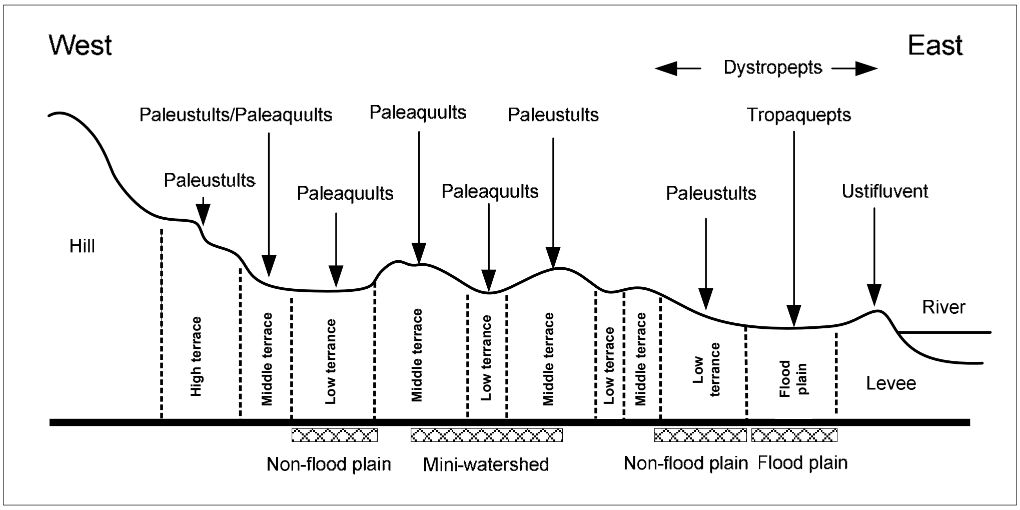
The geomorphologic process originates the soil conditions in relation to landforms, which feature key constraints on agricultural yield, and impede the usefulness of irrigation infrastructures. Geologically, the northeast consists of a massive Cretaceous sandstone plateau (United Nations, 2001). An extensive outcrop of Mesozoic rock occurs on the Korat Plateau rimmed by an escarpment which forms ridges rising from 600-1,000 meters above mean sea level (Cooper, Harbert et al., 2000). The Korat Plateau has a “sauce-pan morphology” and is gently undulating between 150 and 500 meters above mean sea level (Piyasin, 1995). The region is divided into two depositional basins by the Phuphan Range (Figure 2.14). The upper part from the northwest to southeast is the Sakhon Nakhon Basin covering one-fifth of the region. The lower part contains two main rivers, the Chi and Mun, which are situated in the Korat Basin.

The topography of the northeast region consists of rivers, levees, flood plains, low terraces (non-flood plains), undulating middle terraces, and high terraces (hills and mountains). In general, the land is rolling with elevation decreasing from the west to the east and down to the Mekong River. Different landscape patterns are composed of different soil types creating constrained agroecosystems (Figure 2.15). According to the study by Limpinuntana (2001), more than 65% of the land in the northeast is covered by the Paleaquults and Paleustults (Figure 2.16).



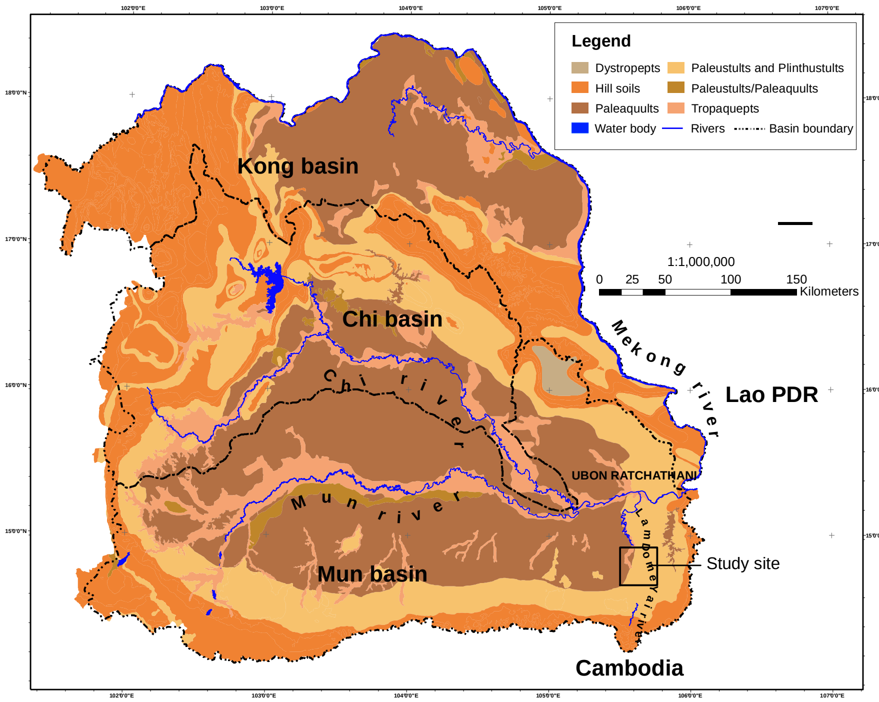
Source: Adapted from northeast regional topographic map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.14 Simplified topographic map displaying two major depositional basins, Sakhon Nakhon and Korat basins of northeast Thailand.



Source: The Northeast Agriculture Extension Centre (1995).

Figure 2.15 Transect of typical soils in relation to landform found in the northeast of Thailand.



Source: Adapted from northeast geological map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.16 Simplified soil map of northeast Thailand.

The Paleaqults are poorly drained and saturated at certain times of the year and are used for RLR cultivation. These soils are found in the low terraces of undulating land and non-flood plains. The Paleustults, often found on the higher terraces, have a sandy texture with low water holding capacity. They are dry for more than 90 days per year, and they are used to grow upland crops such as cassava, sugarcane and kenaf.

The alluvial soils, the Ustifluvents, Tropaquepts and Dystropepts, lie along the Chi and Mun Rivers. The Ustifluvents cover the natural levees while the others are found on the adjacent flood plain. The Tropaquepts, characterized by their fine to medium textures are well drained, and slightly acid and used primarily for horticulture crops. The Dystropepts are fine textured and poorly drained soils. Most soils found in this region have a low level of physical and chemical fertility and limited potentials for crop production. Key soil parameters of a typical regional soil series, Nam Pong, found in Ubon Ratchathani province, indicate its very coarse texture, deficiencies in major nutrients, low organic matter content, low water-holding capacity, and low cation exchange capacities (Table 2.5).

Table 2.5 Properties of Nam Phong series of soils in Det Udom district, Ubon Ratchathani province.

Soil parameter	*Range*	*Mean*
Particle size distribution : 0-30/35 cm (%)		
Sand	88.2 - 94.6	90.9
Silt	3.6 - 9.4	6.5
Clay	1.7 - 3.6	2.6
Particle size distribution : 30/35-60/70 cm (%)		
Sand	88.0 - 95.4	91.2
Silt	3.1 - 10.3	6.7
Clay	1.4 - 4.5	2.1
pH (1:1)	3.9 - 5.2	4.2
Organic matter content (%)	0.39 - 1.79	0.85
Total N (%)	0.02 - 0.08	0.04
Extractable P (Bray II, ppm)	6.1 - 19.0	9.8
Extractable K (ammonium acetate, pH7, ppm)	5.0 - 12.6	8.6
CEC (meq100g^{-1})	0.32 - 1.28	0.83

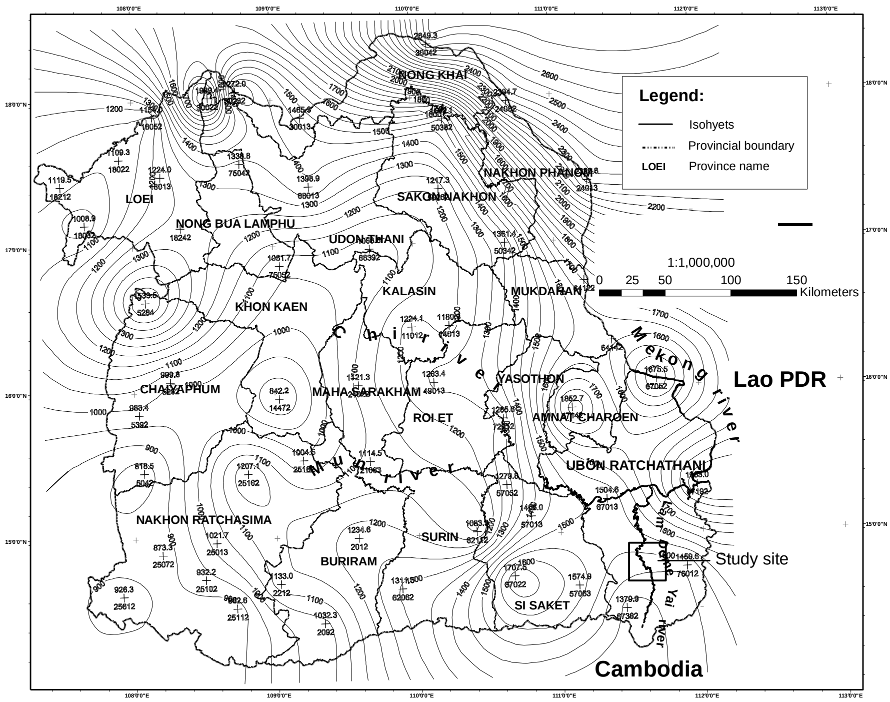
Source: Hampichitvitava and Trébuil, 2000.

However, it is not only the rolling landforms and poor soil quality that are limiting agricultural production. Climatic conditions, in particular, the erratic rainfall distribution also limit farming activities and generate additional risk of crop failure in this region.

2.3.2. Climatic Conditions

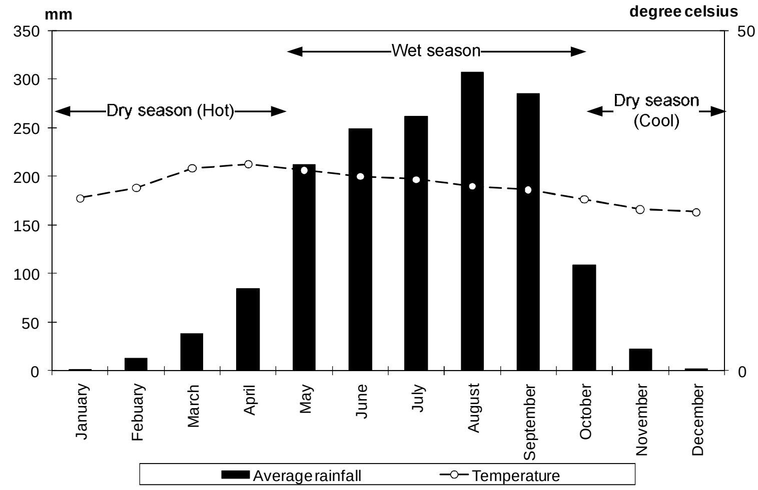
Thailand’s climate is under the influence of seasonal monsoons that determine its major seasons. Average rainfall in the northeast region is 1,200 mm per year, which is similar to other regions. Spatially, rainfall is higher in the northeastern part of the region and gradually decreases westwards up to Nakorn Ratchasima province in the southeast (Figure 2.17).

The southwest monsoon brings moisture from the Indian Ocean during the wet season from May to October. But probability of high rainfall is found only for two months: August, and September (Figure 2.18). At the end of the wet season, the dry and cold northeast monsoon from mainland China settles in November. Consequently, this region faces very dry and very hot conditions for about 6 months until April. At the beginning of the rainy season (May-July), the occurrence of rainfall is highly variable and early season drought in June and July is likely to happen when rice seedlings have to be transplanted (Figure 2.19). Moreover, a late season drought can also occur in September and October during the RLR reproductive phase. High rainfall and a water table that has risen up close to the surface in August and September limit the effects of dry spells during this period. However, devastating floods may occur if exceptionally high rainfall results from depressions following downgraded cyclones originating in the South China Sea. The groundwater level generally recedes quickly after mid-October making rice susceptible to the risk of late season drought in higher paddies causing significant yield reduction.



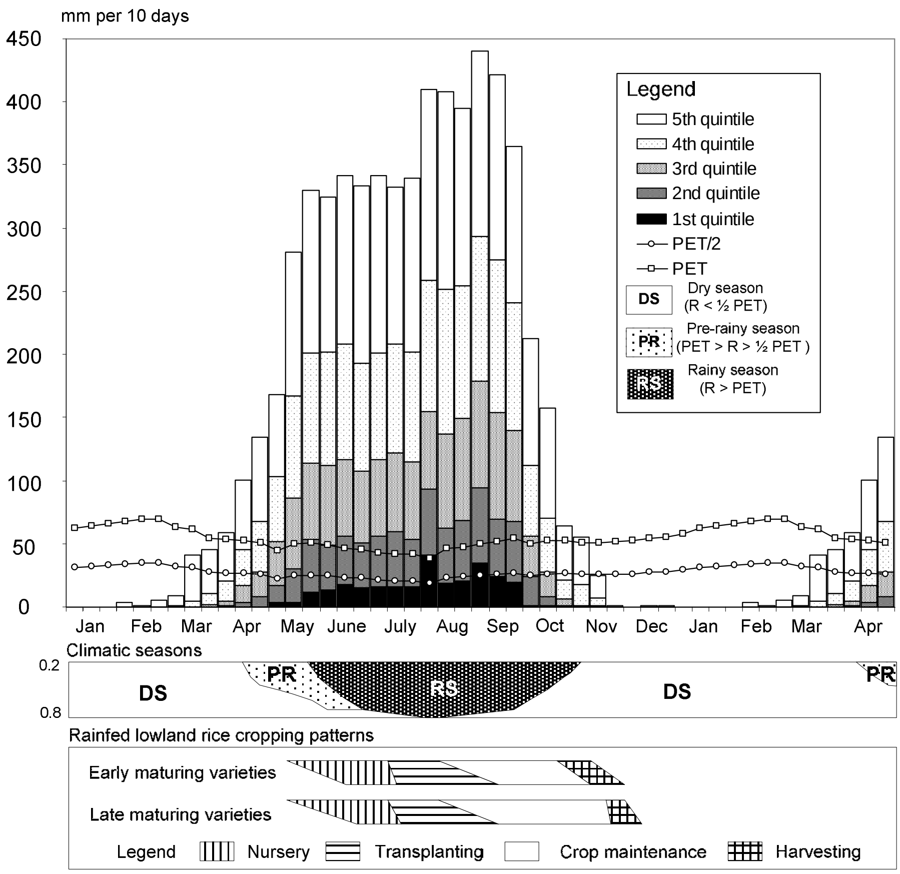
Source: Adapted from northeast regional rainfall distribution map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.17 Annual rainfall distribution in the northeast of Thailand and location of the research site in Lam Dome Yai watershed, Ubon Ratchathani province.



Source: Regional Meteorological Centre, Ministry of Information and Communication Technology, Ubon Ratchathani.

Figure 2.18 Average monthly rainfall quantity and temperature of Ubon Ratchathani province, Thailand.



Source: Regional Meteorological Centre, Ministry of Information and Communication Technology, Ubon Ratchathani.

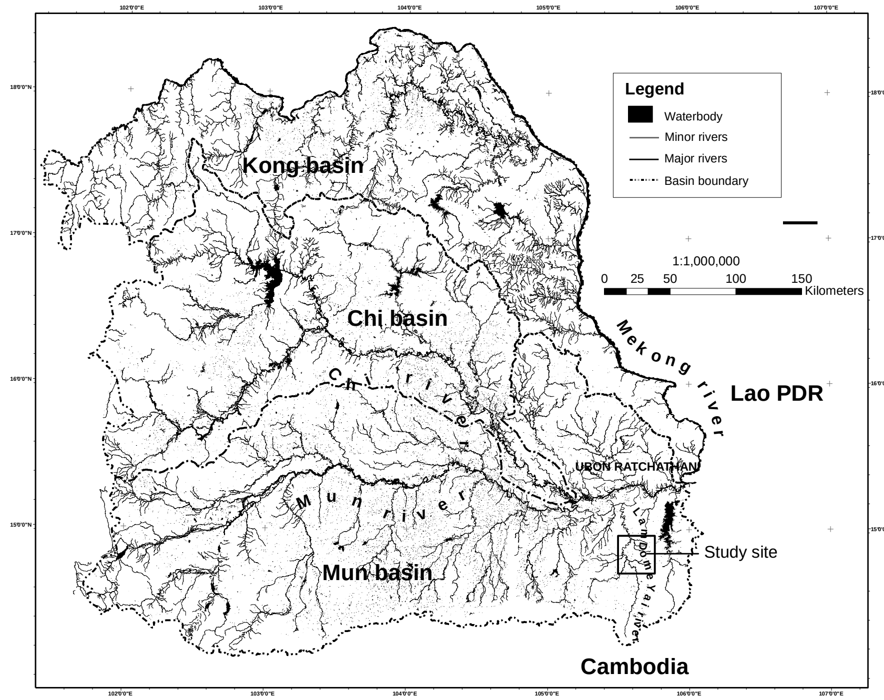
Figure 2.19 Frequential climatic analysis of Ubon Ratchathani province and related RLR cropping patterns (1954-2003).

Supplementing water during dry spells is a way to alleviate drought stress. Therefore, many irrigation infrastructures have been implemented to improve water availability, but the effectiveness of these infrastructures is very limited because of unfavourable topographic and soil characteristics. Thus, the rainwater amount and its distribution still play a crucial role in determining successful agricultural production. But erratic rainfall distribution has farmers adapting their cropping calendar and practices to different field conditions (upper, middle, lower paddies) such as soil moisture and water accessibility.

2.3.3. Hydrosystem and the Evolution of Irrigation Infrastructure

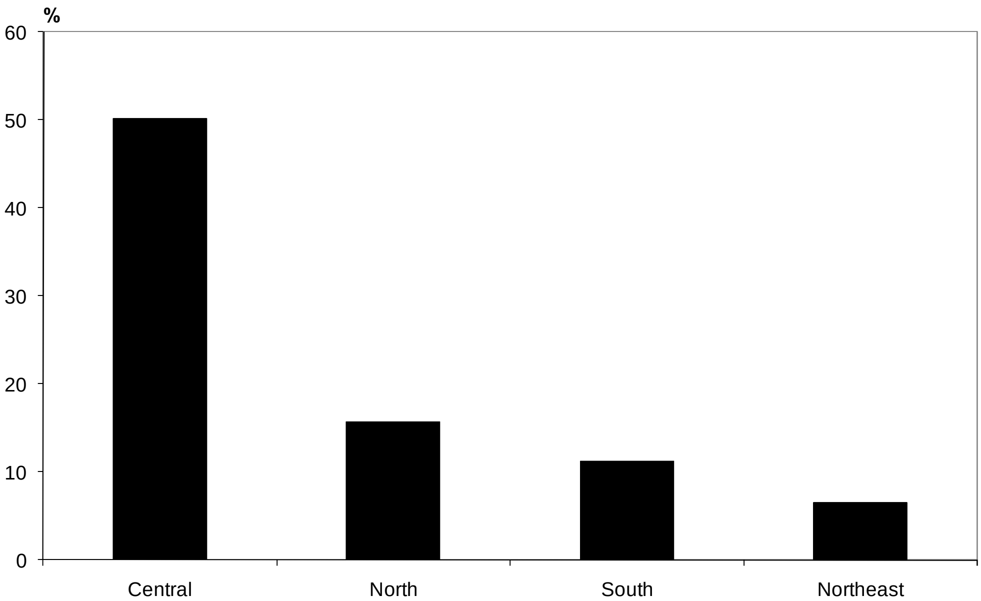
Based on the regional hydrosystem, the northeast consists of three major basins: the Kong, the Chi and the Mun basins (Figure 2.20). All tributaries in the Kong Basin flow eastwards into the Mekong River. The Chi and Mun are main rivers of the Chi and Mun basins respectively. These two rivers originate at Phetchabun and Dong Prayayen mountain range in the western part of region, separating the Central plain and the northeast region. The Chi River joins the Mun River in Ubon Ratchathani province, flowing eastwards to join the Mekong River at the Thai-Lao PDR border. The Mun Basin is the largest one with a coverage area of 69,711 km^2, followed by 57,422 km^2 for the Kong Basin and 49,477 km^2 for the smallest Chi Basin (Wirojanagud and Sriwaoramat, 2000).

Irrigation infrastructures have been built to improve water availability for agricultural production and generate hydropower electricity throughout the kingdom, but the northeast region received less attention in the early days. Water improvement schemes have allocated resources to this region since 1960, but the usefulness of and access to irrigation facilities is still very limited. Although the northeast has the largest rice producing area of the country, only 6% of its paddy fields were irrigated in 2005 (Figure 2.21). Inadequate access to irrigation forces agricultural production to depend mainly on highly variable rainfall and successful crops are still relying on “a bet on the monsoon” approach.



Source: Adapted from northeast regional hydrosystem map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.20 Hydrosystem map displaying three major basins, Kong, Chi and Mun, in northeast Thailand.



Source: Agricultural Statistics of Thailand, Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.21 Share of irrigated farm land by region, Thailand (2005).

Before the 1960s, all the major irrigation projects in Thailand were located in the central and northern regions. The northeast hydrosystem was neglected until the systematic development of irrigation systems began with the first National Economic Development Plan (1961-1966). The first large-scale irrigation project completed in the northeast in 1965 was the Nam Phung Dam in Sakhon Nakohon province, upper northeast Thailand. Following this project, the Chi-Mun Basin saw the construction of the Ubolrattana, Sirinthorn and Chulaporn hydropower dams and reservoirs, and a number of irrigation dams and weirs, including the Lam Pao, Lam Pra Phloeng, Lam Takhong, and Lam Nang Rong dams. The Pak Mun Dam is the latest multi-purpose irrigation project and started to operate in 1994 (Table 2.6).

In 1978, a water policy for the northeast region was planned in the National Master Plan. It followed a two-pronged approach: (i) the effective distribution of available water resources from large reservoirs and reliable rivers to the people adjacent to these sources, and (ii) the development of small water resource projects to meet basic water requirements of the local communities living some distance away from large reservoirs and reliable rivers (Asian Institute of Technology, 1978; The World Commission on Dams, 2000). As a result, more medium-sized irrigation projects were constructed in the northeast region. Between 1980 and early 2000, some of those projects were located in Ubon Ratchathani province (Table 2.7).

Because the topographic and soil characteristics of the northeast are not well suited to large-scale irrigation projects, the current water resources development plan in the Chi-Mun Basin confirms a strategy centred on the development of small-scale water resources (Khon Kaen University, 1994; Progress Technology Consultant Co. Ltd., 2005). For instance, in Ubon Ratchathani province, small-scale irrigation infrastructures at the community level have been encouraged since 1981 (See appendix 2).

At the household level, the development of on-farm water resources based on tens of thousands of small farm ponds (storing a maximum of some 1,260 m^3 of water), under the responsibility of the Agricultural Land Reform Office (ALRO), Ministry of Agriculture and Co-operatives, has been well-adopted by farmers during the past 15 years.

Table 2.6 Medium-to-large scale irrigation infrastructure built in northeast Thailand (1965-1994).

Completed in year	Project name	Primary purpose	Location: District	Location: Province	Storage capacity (10^6x m^3)	Irrigation area (ha)
1965	Nam Phung Dam [1]	Hydroelectricity	Phupan	Sakon Nakhon	165	na
1966	Ubolrattana Dam [1]	Hydroelectricity	Ubolrat	Khon Kaen	2,263	48,000
1969	Lam Pao Dam [2]	Irrigation	Muang	Kalasin	2,450	50,288
1969	Lam Phra Phloeng [2]	Irrigation	Pak Thong Chai	Nakhon Ratchasima	152	na
1969	Lam Takong Dam [2]	Irrigation	Si Que	Nakhon Ratchasima	324	20,406
1971	Sirinthon Dam [1]	Hydroelectricity	Sirinthon	Ubon Ratchathani	1,996	24,320
1972	Chulabhon Dam [1]	Hydroelectricity	Khonsan	Chaiyaphum	188	11,376
1982	Lam Nang Rong Dam [2]	Irrigation	Lahansai	Buriram	150	18,098
1994	Pak Mun Dam [1]	Hydroelectricity	Khong Chiam	Ubon Ratchathani	na	25,600

na: not available
Source: [1] Electricity Generating Authority of Thailand, Ministry of Energy, Bangkok.
[2] Royal Irrigation Department, Ministry of Agriculture and Co-operatives, Bangkok.

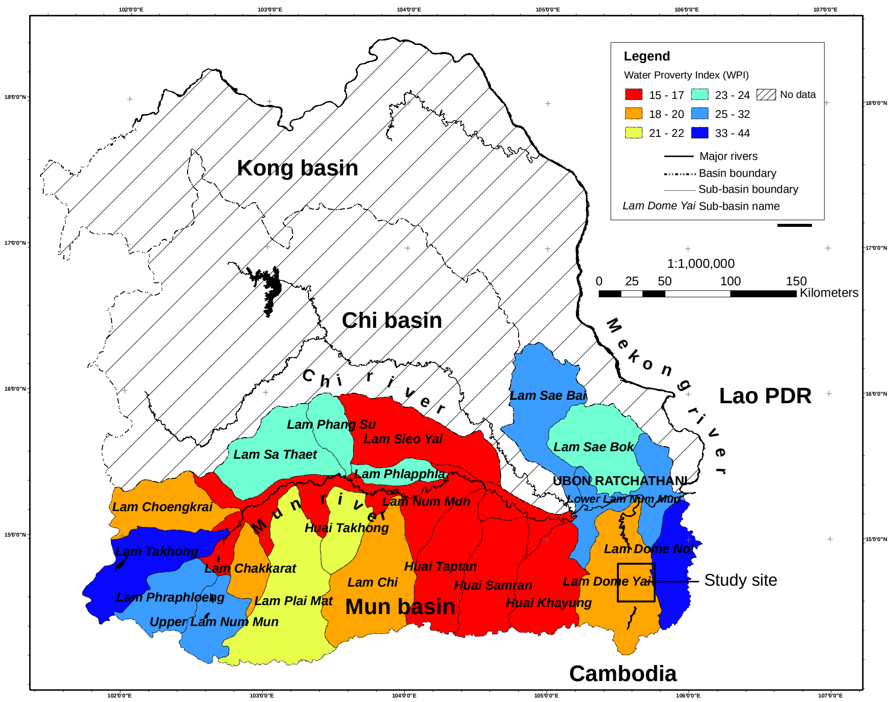
Table 2.7 Medium scale irrigation schemes built in Ubon Ratchathani province (1951-2003).

Completed in year	Project name	Type	Location: Sub-district	Location: District	Storage capacity (10^6 x m^3)	Planned irrigated area (ha)	Actually irrigated area (ha)	Actual/Predicted irrigated area (%)	Cost (x 1000 euros)
1951	Nong Lao Hin	Reservoir	Sank Hao	Khung Nai	2.3	160	107	67	na
1953	Hua Wang Deang	Reservoir	Pho Sai	Phibunmungsaharn	0.7	88	88	100	na
1953	Nong Chang Yai	Reservoir	Hua Raue	Muang, Ubon	7.7	720	689	96	na
1953	Sa Ming	Reservoir	Nong Bok	Laosuekok	1.0	120	23	19	na
1984	Hua Tum Kae	Reservoir	Kum Chareon	Trakarnphutphon	13.7	1,863	1,863	100	na
1986	Lam Dome Yai	Reservoir	Muang Det	Det Udom	1.6	240	na	na	550
1987	Hua Jun La	Reservoir	Klom Pradit	Num Yeun	16.9	2,000	2,000	100	na
1988	Lower Hua Phalan Sua	Reservoir	Klom Pradit	Num Yeun	27.7	932	932	100	na
1994	Hua Wang Yai	Reservoir	Klom Pradit	Num Yeun	8.0	576	na	na	na
1999	Hua Bang Koy	Weir	Kam Pom	Khemmarat	1.0	320	na	na	780
2003	Hua Den Ha	Reservoir	Hua Kar	Buntharik	12.0	na	na	na	na
2003	Hua Saphongnoi	Reservoir	Hua Kar	Buntharik	15.0	na	na	na	na

na: not available
Source: Irrigation Office, Region 7, Royal Irrigation Department, Ministry of Agriculture and Co-operatives, Ubon Ratchathani (2006).

A study conducted by the Progress Technology Consultants (2005) quantified and ranked the water-related poverty of each of the sub-basins in the Mun Basin by use of the Water Poverty Index (WPI). The WPI has been conceived as an interdisciplinary index integrating both physical and social parameters in a structured framework to identify and assess poverty in relation to water resource availability (Sullivan and Meigh, 2007). A low WPI score means a higher degree of poverty in relation to water resources. A low WPI also indicates that agricultural production is not only constrained by the natural conditions but also by poor water management. In this WPI assessment of that study, there were some shortcomings due to the lack of relevant environmental data to meet WPI criteria. However, the study is useful in that it provides an overview of water- poverty relations in the Mun Basin. In this basin, low WPI assessments have been recorded in many rainfed sub-basins in contrast to the sub-basins with large dams, such as Lam Takong and Lam Dome Noi where the Lam Takong and Sirinthon dams are located respectively (Figure 2.22). This figure also shows that the Lam Dome Yai watershed is adjacent to a high WPI, the Lam Dome Noi watershed. But the Lam Dome Yai is still among relatively low WPI sub-basins because of the unavailable irrigation network from the Sirinthon reservoir.

Irrigation projects in the northeast are likely to evolve from a state-controlled and centralized type of management (large dams) to a more decentralized, often individual type of management like in the case of small farm ponds. However, water accessibility through irrigation is still not region-wide. Relying on erratic rainfall causes instability of farm production leading to insecure household income. These resource-poor farmers have to find other sources of income through off-farm employment, which becomes more convenient due to the well connected transportation network.



Source: Adapted from northeast regional hydrosystem map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002), and Water resource management plan in the Mun Basin, Progress Technology Consultant Co. Ltd. (2005).

Figure 2.22 Water Poverty Index (WPI) of sub-basins in the Mun Basin, lower northeast Thailand (2005).

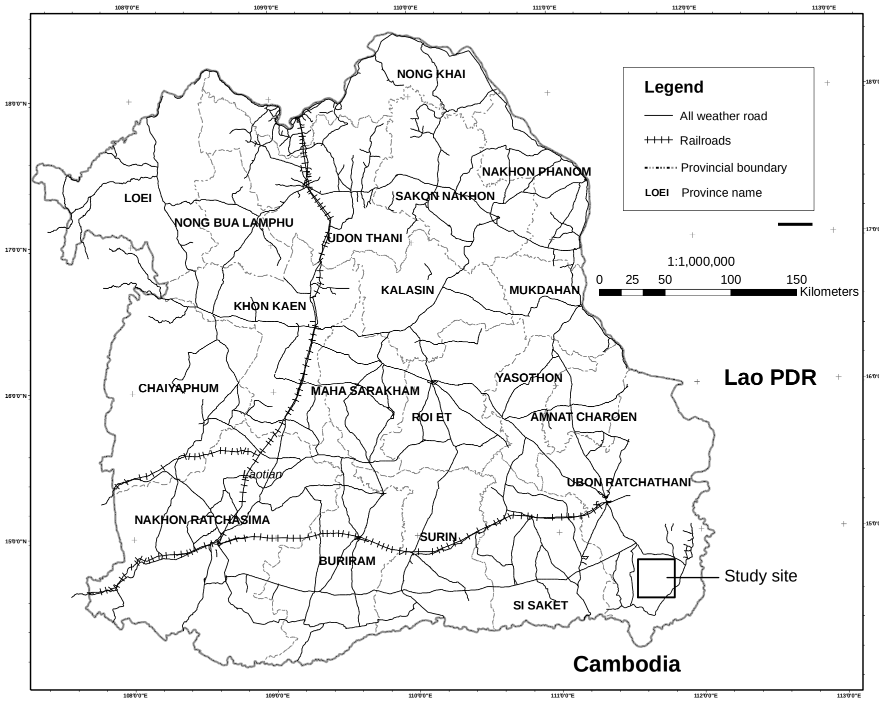
2.3.4. Change in Communication Infrastructure and People Mobility

Transportation links emerge to serve the increasing degrees of commercialization and industrialization, raising health and education standards, and changing government policies (Hornby and Jones, 1993). These links increasingly become an important interacting component to support commodity transportation and to stimulate people mobility.

The most convenient way to deliver agricultural inputs and products across the northeast region is the road network. Other types of transportation, such as trains, are hardly accessible because they serve only a few provinces. Historically, the regional transportation system was planned to mainly serve the purpose of military defence during the "Vietnam War" and to move labour to urban areas and factory sites in the central and eastern regions.

Completed in 1992, the railway was the first main transportation system to connect Bangkok and Nakhon Ratchasima, followed by Nong Khai in the northern part, and Ubon Ratchathani in the southern part (Promjuy et al., 2003). However, this early development stagnated, limiting accessibility to railway. Only two main railway tracks link ten provinces in the northeast to Bangkok. In contrast, the road network has been extensively developed to link the region with Bangkok through regional hubs in Nakhon Ratchasima and Khon Kean provinces (Figure 2.23).

The road network has been continuously upgraded during the past decades. Its current high quality is an important factor in the delivery of agricultural inputs to remote areas and collection of farm products; moreover, it facilitates the flow of workers from any village to large cities because of its accessibility.

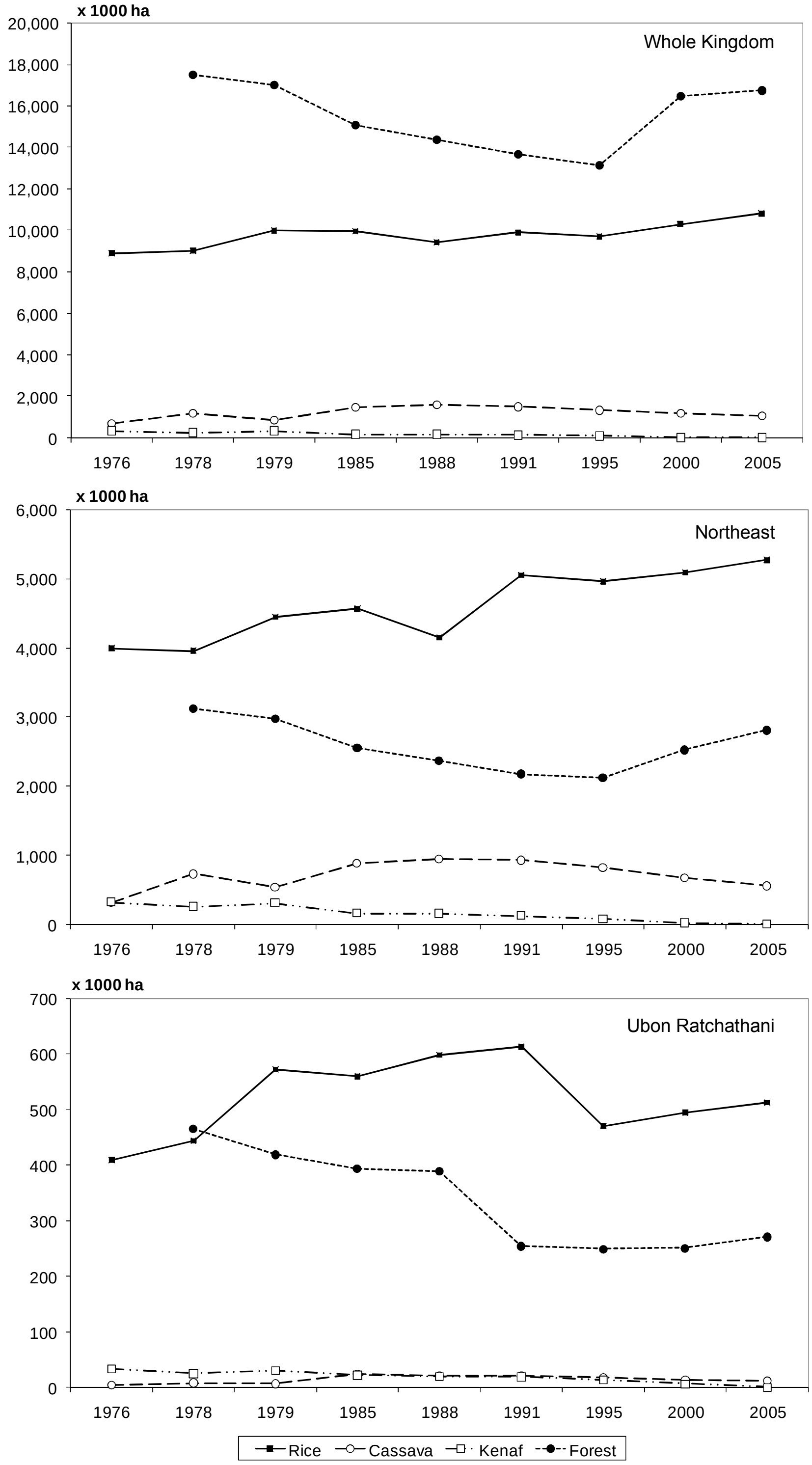


Source: Adapted from northeast regional transportation network map, Geographic Information System Centre, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 2.23 Road and railway networks in northeast Thailand.

2.3.5. Land Use

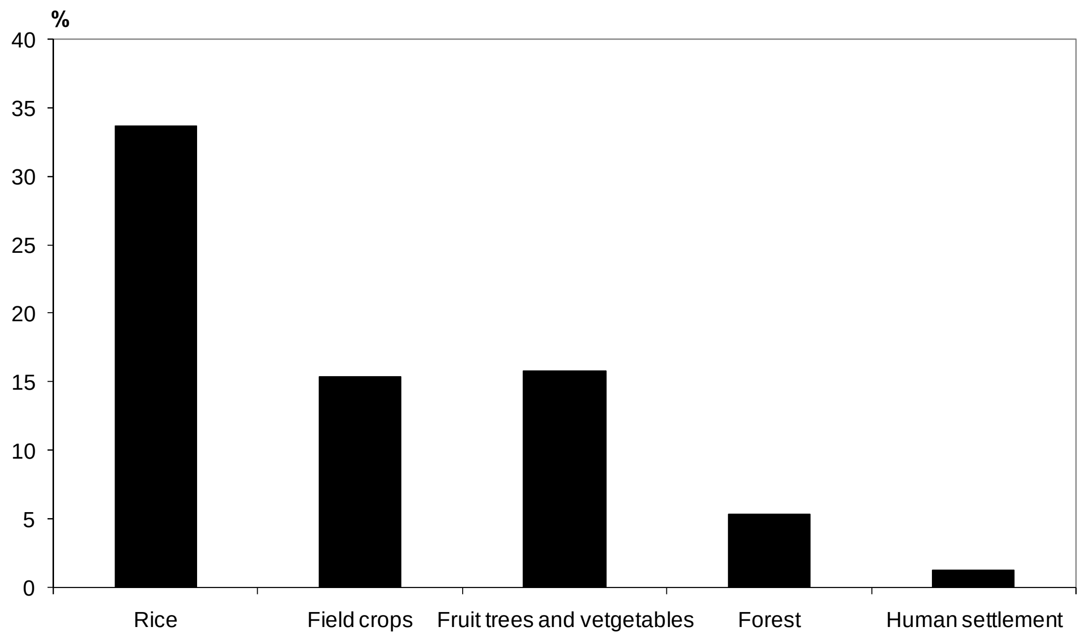
National population and economic growth and expanding options for the use of modern technologies have influenced changes in land use and land cover. Figure 2.24 shows that during 1970-90, the forest cover decreased because of the demand for timber and farming land. Up until the 1970s, the northeast region was the largest producer of cassava and kenaf. After the 70s, the production of kenaf decreased rapidly due to declining prices while cassava was promoted because of the high demand from the European Union until the late 80s. The forest area stabilized following a ban on logging in 1989 and launch of a reforestation policy by the Thai government.



Source: Agricultural Statistics of Thailand, Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.24 Evolution of production areas for rice, cassava, kenaf, and forest area in Thailand, the northeast region (1976-2005).

The northeast farm land covers about 8.9 million ha with rice occupying one third of this area (Figure 2.25). Nevertheless, there are various regional agroecosystems determined by landform characteristics related to different soil conditions and water availability. The hill lands are found in mountainous areas of the southern part at the Panomdongruk and Sankampaeng ranges, the west at the Petchaboon range, and the north at the Phuphan range. The soils found in these areas are more fertile than other systems (KKU-Ford Cropping System Project, 1982). Consequently, the hill lands generally produce good yields of maize, upland rice and various crops in the rainy season.



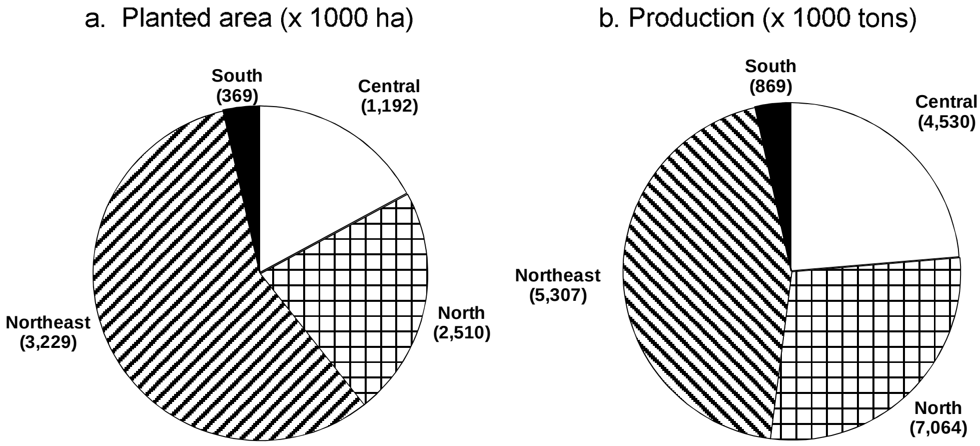
Source: Agricultural Statistics of Thailand, Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.25 Main type of land use in northeast Thailand (2005).

The mini-watershed is the most common agroecosystem throughout the northeast region covering about 4.9 million ha. Four micro-landscapes are defined in a mini-watershed. The upper, middle and lower paddies and the upland area for cash crop production (Grandstaff, 1988; Polthanee, 1997). The non-flood plains cover about 2.9 million ha on the lower terrace, with clayey and fertile soils, and sufficient water accumulation for rice transplanting in July or August. Moreover, with a heavy clay layer beneath the top soil, the water table is only 1-2 metres preventing water loss through infiltration (KKU-Ford Cropping System Project, 1982). This agroecological zone is suitable for RLR cultivation. The flood plains cover about 1.1 million ha along the Chi and Mun Rivers and are inundated by the annual flood caused by the overflowing of the river banks. The pattern of cultivation is very similar to the non-flood plains, RLR being the main crop with a subsequent crop of vegetables on part of the land. Because 85% of rice in the northeast is grown under rainfed conditions (Jongdee et al., 2006), the characteristics of RLR ecosystem and common local farming practices in mini-watersheds need to be precise.

2.4. Characteristics of Rainfed Lowland Rice Production

The world's 40 million ha of RLR account for 29% of rice land and 19% of rice supply (Wade, Fukai et al., 1999). Most of the RLR areas are located in Asian countries, particularly in the South and Southeast. Nearly 75% of the rice produced in the wet season is grown in rainfed areas where monsoon rain is the only source of water supply (Food and Agriculture Organization, 2004). Out of about 10 million ha of rice land in Thailand, RLR is the predominant type, accounting for 67% of the total rice land area; RLR accounts for one third of rice land in the northeast region (Jongdee et al., 2006). The rainfed lowlands are defined as areas where rice is grown in unirrigated, level to slightly sloping bunded fields that have non-continuous flooding of variable depth and duration caused by rain water (Wade, 1999; Zeigler and Puckridge, 1995). RLR production in this region has low productivity at an average of 1.8 t ha^{-1} (Somrith, 1997). Figure 2.26 shows the lowest rice yield produced in the northeast region compared to other regions. .



Source: Agricultural Statistics of Thailand Centre for Agricultural Information, Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 2.26 Rice planted area and production by region (2007).

2.4.1. Mini-watershed Characteristics

Local farmers manage their farm production based on the differences of landform reflecting soil types and water availability (Figure 2.27). In a mini-watershed, the uplands account for 20-30% of the area and consist of unbunded fields where cassava, sugarcane, kenaf and upland rice are cultivated; the uplands are also favoured for cattle grazing and house settlement. The upper paddies where cultivation depends critically on rainfall are used to produce early-maturing rice only in some years. Some farmers grow direct-seeded rice in this area to avoid the problem of insufficient water availability at rice transplanting. There are some farmers producing one or two non-rice upland crops during the rainy season in upper paddies. The middle paddies probably contain the most productive land since farmers have more water control with less risk of flooding. In lower paddies, farmers commonly grow late maturing rice varieties every year during the rainy season. Rice-based cropping systems dominate the middle and lower paddies; in some years and in more limited areas, they also dominate upper paddies if water is available.

2.4.2. Local Agricultural Practices in Rainfed Lowland Ecosystems

The soil and water characteristics of different landforms play a role in the selection of different cropping systems and farming practices (Figure 2.27). The middle and lower paddies are planted with rice, followed by vegetables in some areas. Figure 2.28 shows cropping calendars of different agroecological zones found in northeast Thailand.   For rice-based cropping systems, land preparation and rice establishment normally start in mid-June. Water in farm ponds is sometimes used to supply nurseries for early rice establishment in May. But the water is mainly used to alleviate drought effects if a dry spell occurs. Farmers are likely to use the transplanting technique and choose to grow medium to late maturing varieties including the famous aromatic jasmine rice in its glutinous variety (RD6) or non-glutinous (KDML105) type. Some rice farmers use direct seeding in areas where water is likely to be inadequate such as upper paddies. Labour scarcity also drives farmers to save time by broadcasting seeds.

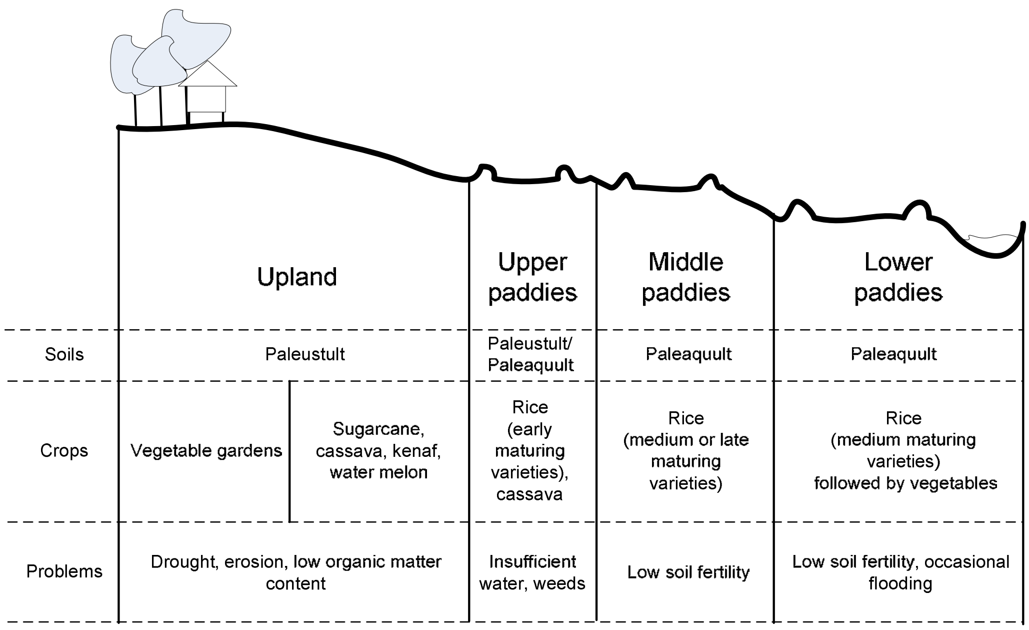
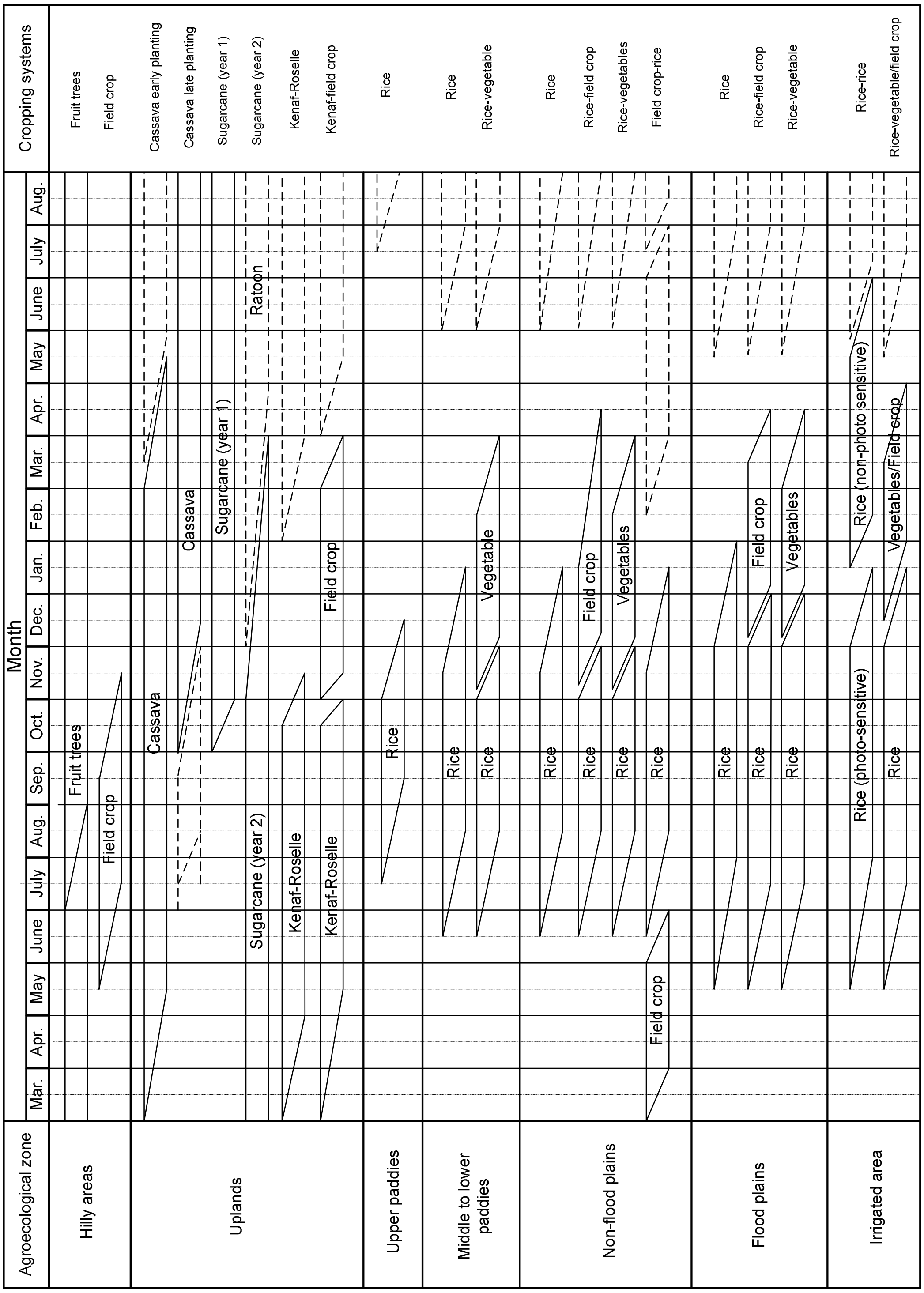


Figure 2.27 Cropping system, soil and ecological problems in relation to spatial organization of mini-watershed in rainfed lowland rice ecosystems of northeast Thailand.



Source: Adapted from An agro-ecosystem analysis of northeast Thailand (KKU-Ford Cropping System Project, 1982) and Natural resource management issues in the Korat Basin of Northeast Thailand: An overview (Limpinuntana, 2001).

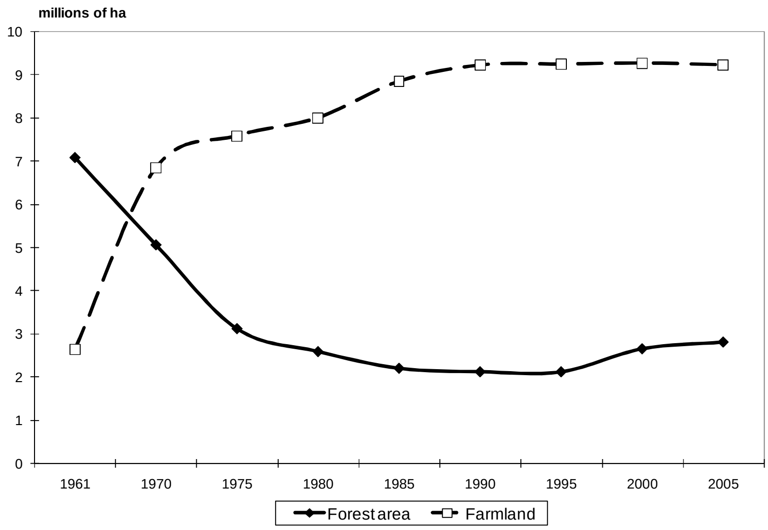
Figure 2.28 Cropping calendars and main crops in relation to different agroecological zones in northeast Thailand.

Transplanting activity starts once the rice seedlings are 30 days old and the soil in the paddies is saturated. After farmers begin transplanting, the length of this activity mainly depends on the availability of family labourers. To allow rice to accumulate enough biomass, farmers usually complete transplanting before mid-September. The early maturing types are always transplanted first in upper paddies that are close to a temporary storage cottage and farm pond, followed by transplanting late maturing rice in lower paddies. This local rice-transplanting practice is carried out in response to the decreasing water level in paddies when harvesting time comes.

According to the agronomic traits of photosensitive rice varieties, early maturing rice ripens in late-October to early November. At this time, water logged in upper paddies usually dries out allowing the farmers to harvest rice more easily and with lower risks of the paddies getting wet causing a lowering of quality. In late November (21st November for KDML 105), farmers begin to harvest late maturing types that are commonly produced for sale. Therefore, farmers with high land and labour ratio usually hire additional labourers because the sooner they can finish harvesting, the higher the paddy quality, which in turn leads to higher prices at sale. These cropping systems and common farming practices have emerged from the agricultural evolutions influenced by natural changes related to demographic, political, and socioeconomic factors. The next chapter will specifically address the recent agricultural transformations and land use changes at the study site.

CHAPTER 3
RECENT AGRICULTURAL TRANSFORMATIONS AND LAND USE CHANGE AT STUDY SITE

Important factors causing the transformation of APS include: (i) demographic pressure due to population increases; (ii) state policies and related projects or regulations; (iii) innovative agricultural changes through the employment of new technologies; (vi) infrastructure development, e.g. transportation systems facilitating integration, and (v) socio-cultural factors related to the northeastern people's ways of thinking, and inherited beliefs (Vityakon, Subhadhira et al., 2004). As a result of these interacting factors, the agricultural area of northeast Thailand expanded rapidly after the early 1960s (Figure 3.1). Since then, farmers have increasingly depended on the state's support via financial loans drawn from the Bank for Agriculture and Agricultural Co-operatives (BAAC), and private local capitalists to purchase farm inputs and consumer goods. Many farmers have become so indebted that their income received from agricultural production is insufficient to meet their basic needs. The best recourse of these farmers is to migrate to search for off-farm employment to help pay back their debts.



Source: a) Forest area 1961-73 from Royal Forestry Department, Ministry of Agriculture and Co-operatives, Bangkok.
b) Forest area and farm land 1986-2005 from Office of Agricultural Economics, Ministry of Agriculture and Co-operatives, Bangkok.

Figure 3.1 Evolution of forest area and farm land in northeast Thailand (1961-2005).

This section specifically documents the characteristics of the study area, including: the evolution of transportation networks; the agricultural production system and land use changes based on interpreted findings from farm surveys; and the analysis of secondary data using Geographic Information System (GIS) and remote sensing tools.

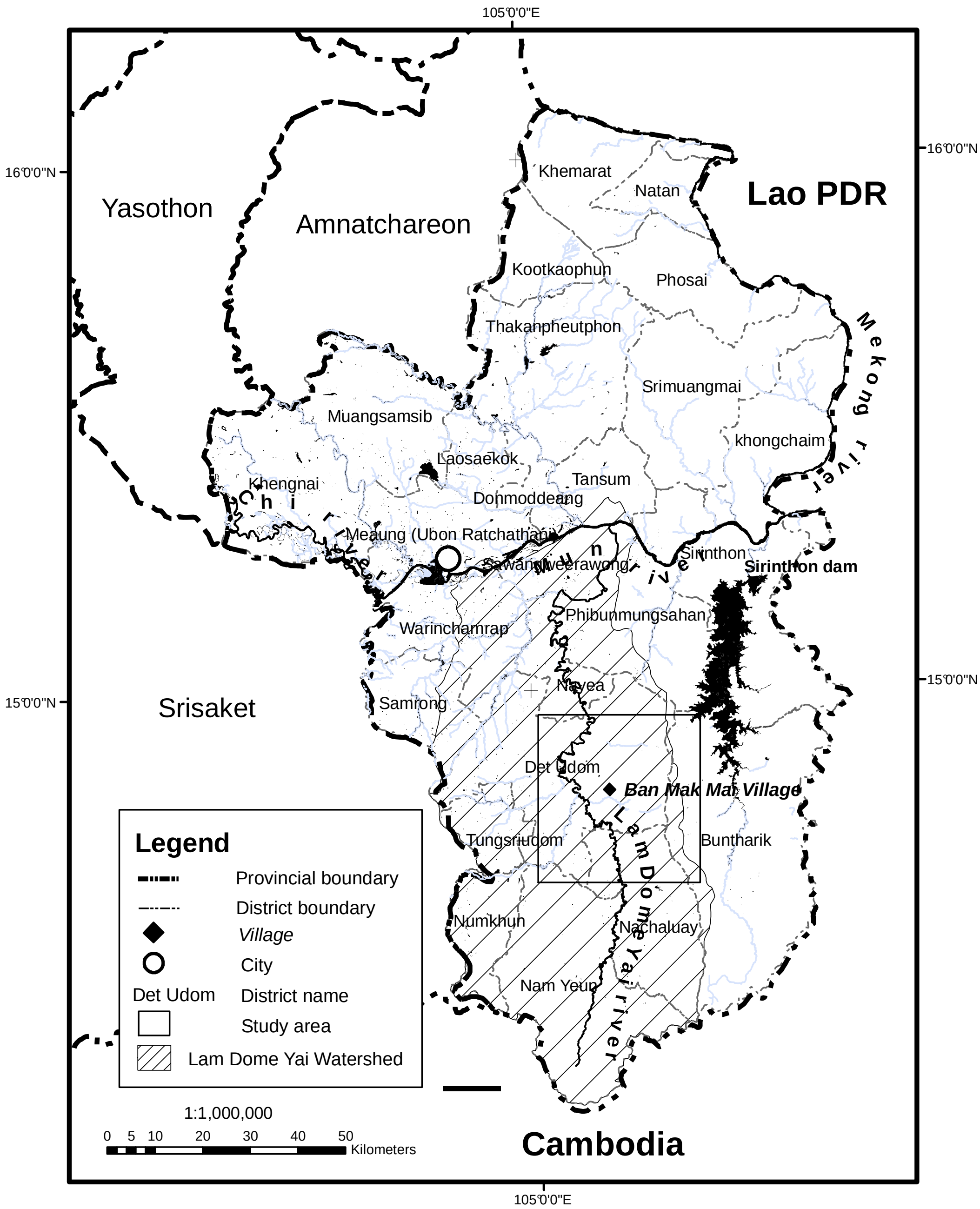
3.1. Location of Study Site

Ubon Ratchathani (often referred to in short as “Ubon” or “Lotus City”) is the country’s easternmost province. This province covers 15,744 km^2 and consists of 25 districts in nine watersheds. The Lam Dome Yai watershed, where my study area is located, is the largest. It is located in the south, covering seven districts and parts of five other districts over a total area of 4,803 km^2 (Figure 3.2). According to the demographic records of NSO (2005), the total population in Ubon was 1,806,000 with only 14.6 % living in urban areas. The mean size of household was 4.6 while the population growth rate was 0.83%. The working aged population (13-60 year old) was 68.32% and roughly 46% of them were engaged in agricultural production.

3.2. Development of the Local Transportation Network in Relation to Agricultural Production and Labour Mobility

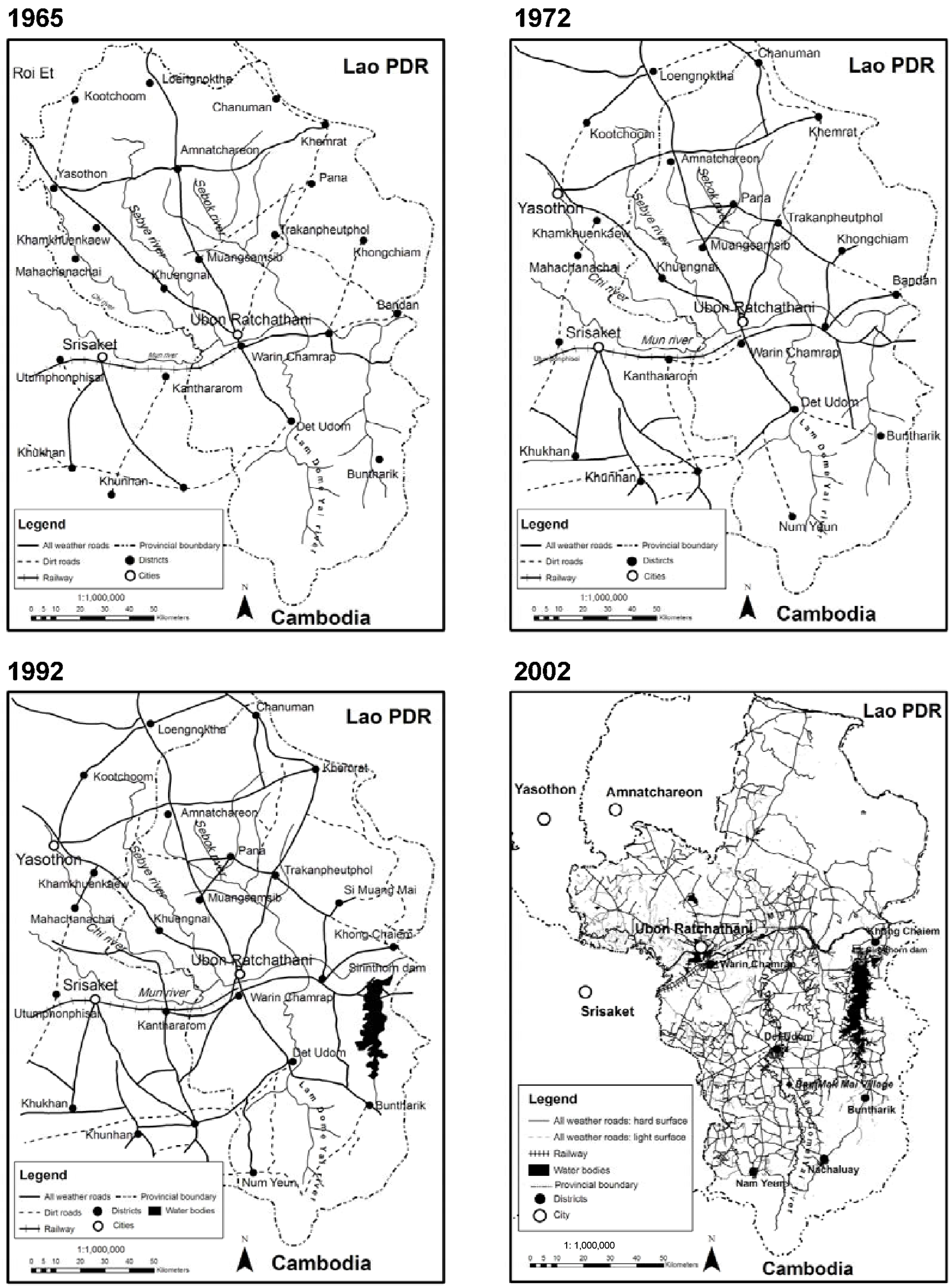
One key development that has influenced the lives of rural dwellers has been the extensive expansion of the transportation network. The first major communication axis was the railway, which was completed in 1930. It connected the central plain to Ubon, through the lower northeast, ending in the district of Warinchamrap. Following the railway, a major road, the so called “friendship highway”, was constructed during the Vietnam War to provide better accessibility for national defence purposes.

The Office of Rapid Rural Development (RRD) was established in 1965 to build more roads to connect people who lived in remote areas to provincial cities (Figure 3.3).



Source: Adapted from northeast provincial boundary map, Geographic Information System Center, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 3.2 Provincial map showing district administrative boundaries and the study site in the Lam Dome Yai watershed, Ubon Ratchathani.



Source: a) Digitized from Map of Provinces in Thailand; 1965 (Loha-aunjit 1965).
b) Digitized from Map of Provinces in Thailand; 1972 (Jareeyapat 1972).
c) Digitized from Map of Highway in Thailand, Highway Department, Ministry of Interior, Bangkok; 1992.
d) Adapted from northeast regional transportation network map, Geographic Information System Center, Faculty of Engineer, Ubon Rajathanee University, Ubon Ratchathan; 2002.

Figure 3.3 Expansion of the local road network in Ubon Ratchathani over the past four decades.

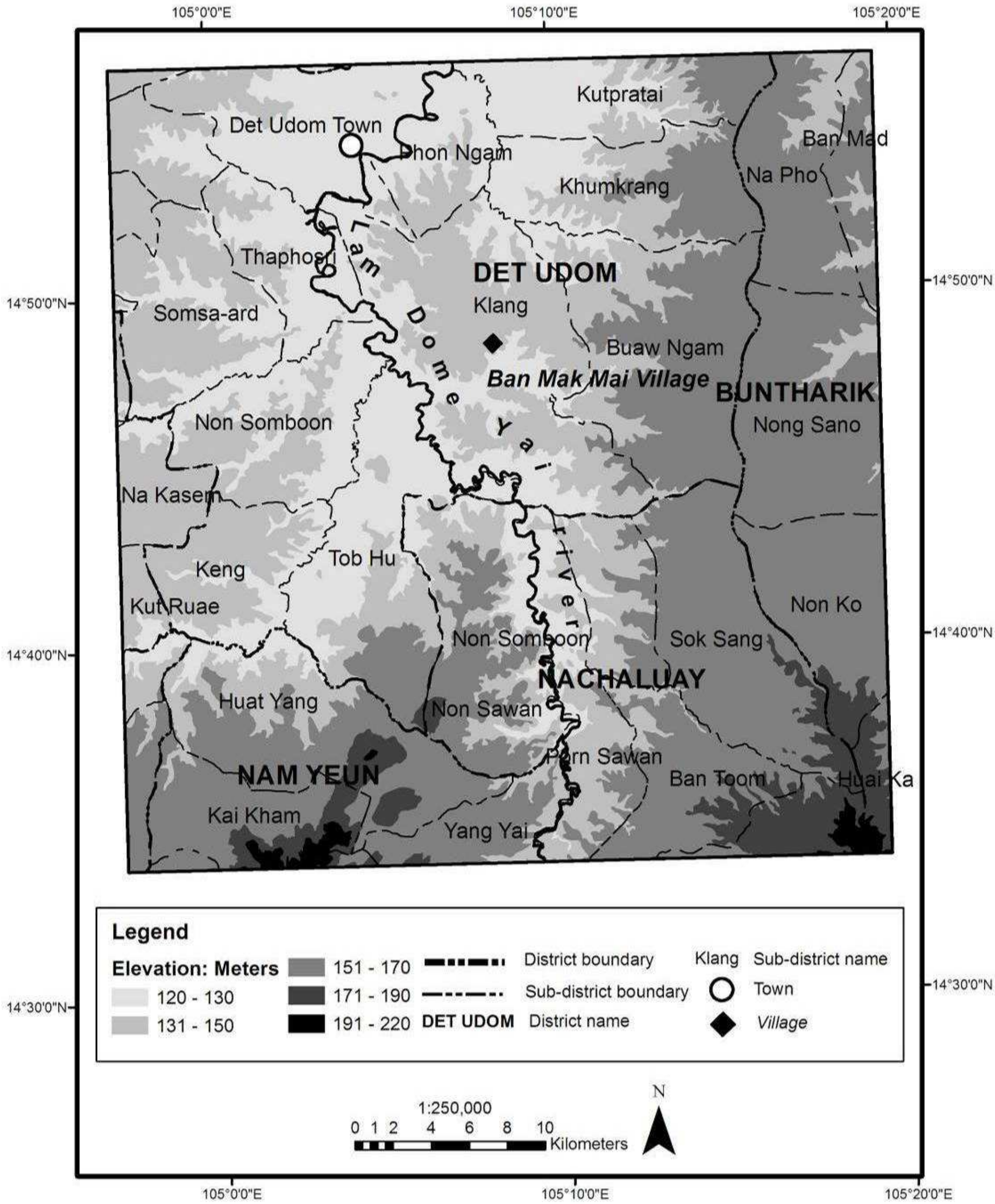
In the early 1970s, the road network provided access to a hub at Det Udom district to people living in the southern part of the province. This was also the terminal of a major transportation network named “Chokchai-Det Udom”, which greatly enabled the delivery of agricultural products, especially rice and kenaf, to the regional hub in Nakhon Ratchasima province. Figure 3.3 clearly shows the extensive expansion of the road networks built in Ubon during the following decades. Because of this transportation network, the access to non-farm employment out of any village is widening. Career change and the movement of farm workers to non-farm sectors have increased, resulting in changes in the use of local natural resource and farming practices.

3.3. History of Local Agrarian System and Land Use Change

The study area is located inside the Lam Dome Yai watershed covering 1,680 km^2 and taking in Det Udom district and the northern part of Na Chaluay district. Its topography is flat (about 1% slope) with an elevation that varies between 120 and 170 meters above mean sea level (MSL) and relatively steep elevation between 170-220 meters above MSL in the southern part (Figure 3.4). Hilly areas are found in the south, and a mini-watershed landform dominates along the Lam Dome Yai River. The dynamics of the agroecological features and socioeconomic dimensions in this area are typical of those observed in the lower northeast region. Information related to such socioeconomic changes matching agroecological transformations is displayed in chronological order in the historical profile (Figure 3.5).

3.3.1. Self-subsistence before the First National Economic Development Plan 1961-66

The first settlers of Ban Mak Mai village migrated from Srisaket province around 1940. They settled on uplands and established rice paddies in lowlands for family consumption. Small-scale diverse agricultural production in mixed gardens was practiced to provide different kinds of food. The forest surrounding the village was also a source of construction materials, fuel, medicinal plants and additional food items. Cattle and buffaloes were raised and used as draft animals in paddies and for transportation. Their manure was an important source of organic fertilizer. Due to its remoteness, Ban Mak Mai village was not affected by the railway or the arrival of rice trading managed by Chinese tradesmen. However, improved transportation encouraged people from other provinces to settle in Ubon Ratchathani province.



Source: Adapted from Ubon Ratchathani topographic map, Geographic Information System Center, Faculty of Engineering, Ubon Rajathanee University, Ubon Ratchathani (2002).

Figure 3.4 Topographic map of the study area in southern Ubon Ratchathani province.

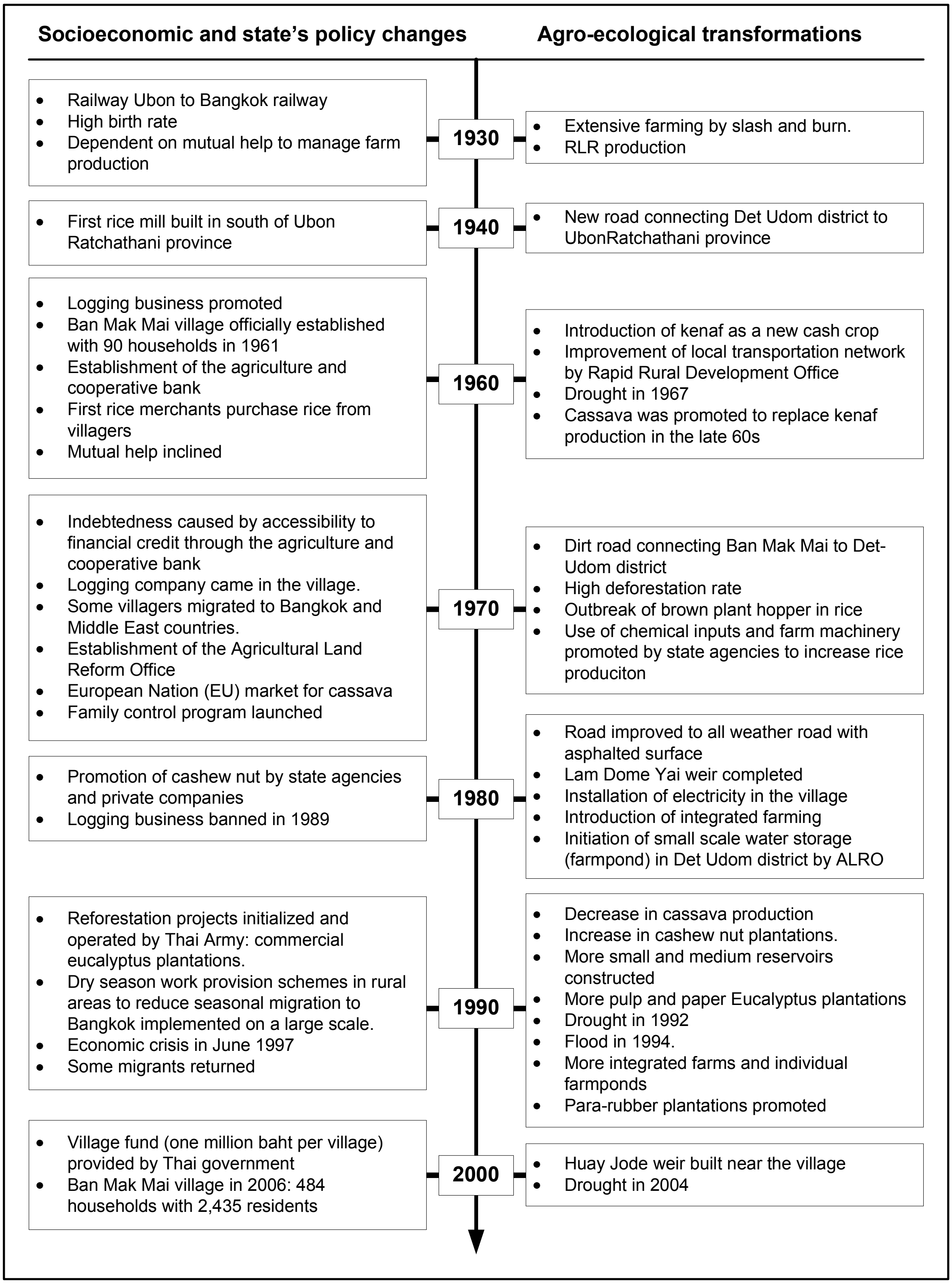


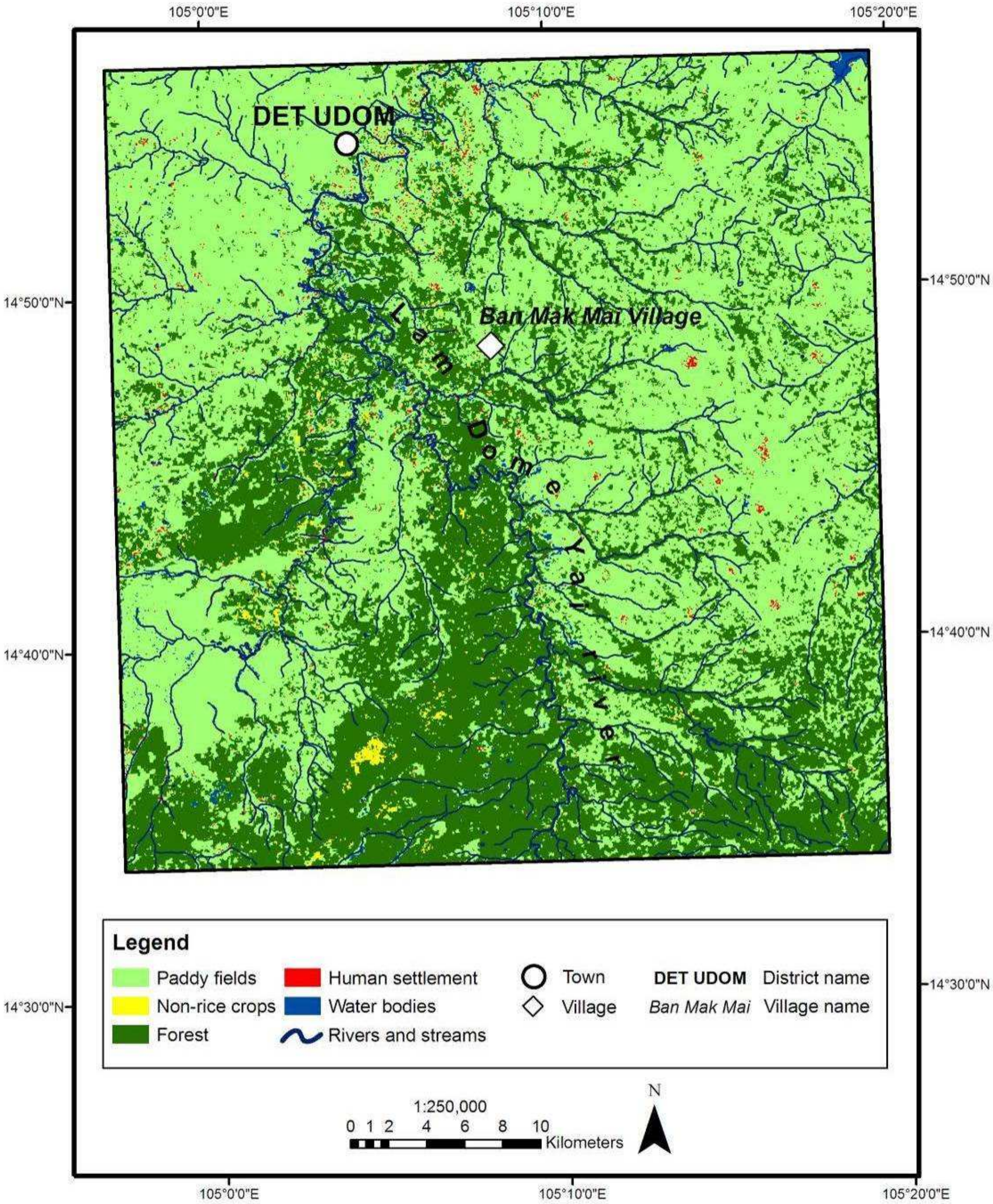
Figure 3.5 Evolution of socioeconomic and agroecological characteristics of Ban Mak Mai village in Klang sub-district, Det Udom district, Ubon Ratchathani province (1930-2000).

3.3.2. Expansion of Farm Land for New Cash Cropping in 1960s and 70s, and Emergence of Labour Migration for Off-farm Employment in the Seventies

In the early 1960s, there were only 90 households in Ban Mak Mai village. During this period, Thailand issued its first economic development plan that was geared to influence changes in APS throughout the whole kingdom. This national economic development plan aimed to promote an industrialized expansion of crops such as cotton, kenaf, cassava, sugarcane, maize, etc. The BAAC established in 1966, provided loans to local farmers at low interest.

The APS of Ban Mak Mai village were affected by these changes. Kenaf and roselle, which were long fibre crops used to produce gunny bags, were the first cash crops introduced to local farmers in the early 1960s, reaching its peak production seven years later. The Chokchi-Det Udom road was an important economic route because many gunny bag factories were established along this road. As a consequence, some farmers abandoned their land to migrate to work in these factories and settle nearby. Since the labour demand was high, the wage was considerably higher than the income received from rice. Gradually, the traditional mutual help system was replaced by hired labourers (Promjuy et al., 2003).

In 1967, the production of kenaf decreased due to its declining price caused by international competition, and because the Thai government shifted its policy: cassava exports were now being subsidized for the European market. Cassava became more favoured by farmers because of its higher price, drought tolerance and less labour intensive production compared to kenaf. However, rice producing areas in lowlands were not affected by the expansion of these upland cash crops and continued to expand. In the study area, these cash crops were not produced at a large scale in this period due to its remote location until the first dirt road to connect this area to Det Udom town was built in 1975. Dense forest cover was still found in the more distant areas to the south of study area, while rice production was the dominant use of land near Det Udom town (Figure 3.6). These two types of land cover were dominating in my study site (Figure 3.7). Farm and labour productivity was higher than during previous decades because of the expansion of farming with draft animals (Manarangsan, 2002).



Source: Landsat MSS taken on 3 January 1973, downloaded from http://glcfapp.umiacs.umd.edu.

Figure 3.6 Land use map highlighting the five main land use types of the study area in 1973 based on supervised classification of Landsat MSS imagery.

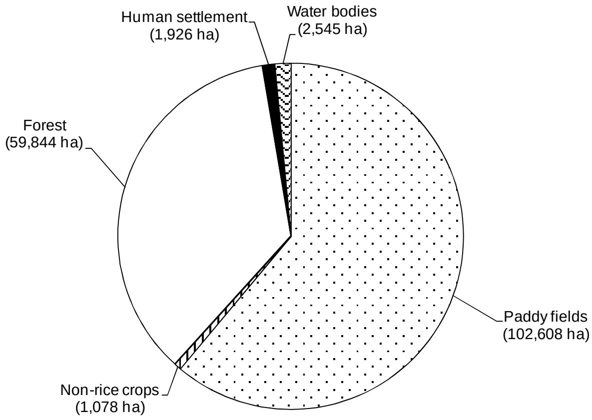
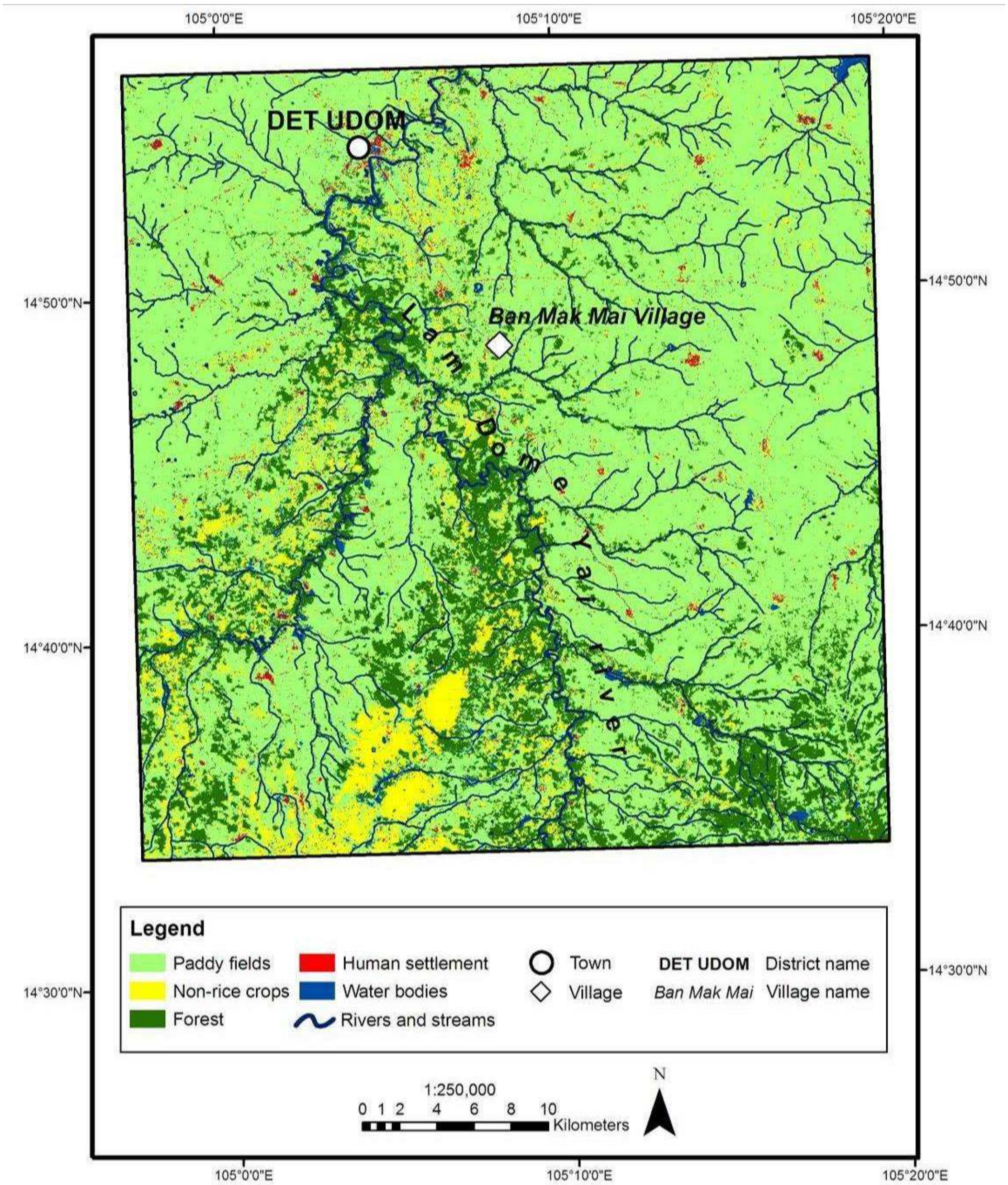


Figure 3.7 Five main land use types in the study area from a 1973 land use map.

Following the promulgation of the Land Code in 1954 and the Land Allocation Occupature Act in 1957, the Agricultural Land Reform Act in 1976 was gazetted. The land tenure policy aimed at improving ownership and tenurial rights, and the opening up of land for new settlements. At the same time, demographic pressures were increasing as a result of the combined effects of national population growth and migration. Many farmers began to convert the forest to upland field crop areas and claim their tenurial rights on the cleared areas.

3.3.3. High Deforestation for Cassava and Timber Production Leading to Forest Conservation Law, and Eucalyptus and Cashew nut Plantations in the Eighties

The high rate of deforestation between 1979 and 1988 was caused by: (i) legal timber concessions; (ii) rapid improvement of the transportation network, and (iii) the demand for farm land, especially to grow field cash crops in upland areas (Faculty of Economics Kasetsart University, 2000). Figure 3.8 shows that the dense forest area that existed in the southern part in 1973 was almost completely replaced by field crops in 1989. This was a consequence of state policies emphasizing rapid economic growth through agro-industrialization to serve the demand of international markets. The 5th National Economic and Social Development Plan implemented during 1982-86 focused on export-led growth, while ensuring the supply of affordable food and relatively low prices of rice to maintain low costs of labour in the industrial sector. The development plan effectively sought to maintain the country's comparative advantage in international competition.



Source: Landsat TM taken on 25 December 1989, downloaded from http://glcfapp.umiacs.umd.edu.

Figure 3.8 Land use map that highlights the five main land use types of the study area in 1989 based on supervised classification of Landsat TM imagery.

Since producing rice did not provide enough income to meet basic human needs, cash crops with high-economic returns such as kenaf and cassava were extensively grown in the 70s and 80s (Barnaud, Trébuil et al., 2004). Furthermore, the extensive road network stimulated more labour migration to the industrial sector. Because migrant workers from this area were not skilled workers, their jobs were not secure and wages were low. As most of the migrants were ethnic Lao, their means of subsistence remained strongly linked to rice, and they maintained close contact with the rest of the family in their home villages. The pattern of seasonal migration was increasingly prominent. Once the RLR growing season started, the seasonal migrants returned home to help with the transplanting and harvesting to ensure adequate rice production for their family consumption and a surplus for sale.

The loss of biodiversity, particularly rice varieties, is another emerging concern. In 1977, an aromatic glutinous photosensitive rice variety, RD6, was introduced to the farmers. With its excellent gain quality and adaptability to the harsh agro-ecosystem of the northeast, this rice variety has gradually replaced many traditional glutinous varieties used as staple food in northeast Thailand. This photosensitive rice is usually planted in lower paddies where water availability is more secured. The lower paddies are also favoured for another aromatic but non-glutinous main variety, KDML105. KDML105 is mainly produced for sale due to its high demand on both domestic and world markets and high market price (roughly a third higher than other cultivars), while some traditional early-maturing varieties are still produced for family consumption. In 1978, RD15, a non-glutinous, aromatic, early-maturing type, was introduced and considerably grown to be sold in early markets (Bureau of Rice Research and Development, 1999). Because of its early maturing trait, RD15 is also a choice for farmers in alleviating labour constraints during harvesting time.

Because water availability was the focus of development schemes by Thai governments, small-scale irrigation infrastructures were built in this area. Apart from weirs and community reservoirs, farm pond construction was first subsidized by the ALRO in the late 80s. This water improvement motivated farmers to purchase more motorized water pumps. Draft animals were gradually replaced by two-wheel hand tractors to accelerate land preparation. These changes provided local farmers with spare time, enabling them to be hired by their neighbours or even migrate to work off-farm jobs. In 1989, rice producing areas and non-rice crops were the dominant land uses, while forest cover had sharply decreased (Figure 3.9).

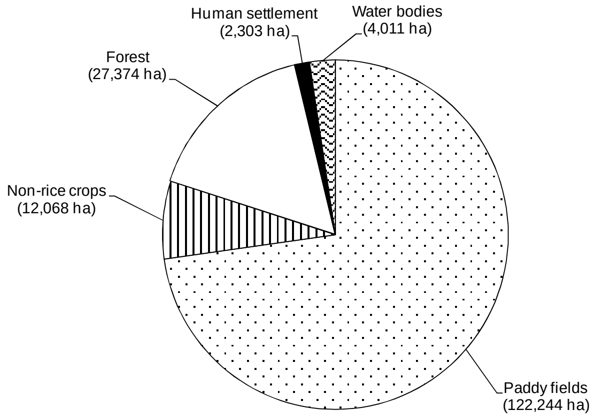


Figure 3.9 Five main land use types in the study area from a 1989 land use map.

Rising agricultural production costs, rising demand for consumer goods and other domestic products, and the availability of credit from BAAC were major reasons for the increasing indebtedness of farmers. Therefore, family workers had to migrate to look for off-farm employment to generate supplementary income; moreover, workers still faced the ever present risk of unemployment because of the nature of the local industrial sector and its low capacity to absorb a labour force (Manarangsan, 2002). Successive Thai governments tried to implement policies to alleviate rural poverty and to curb labour migration. Among these policies, the conversion from monoculture crop systems to mixed cropping systems has been widely promoted since the early 1990s.

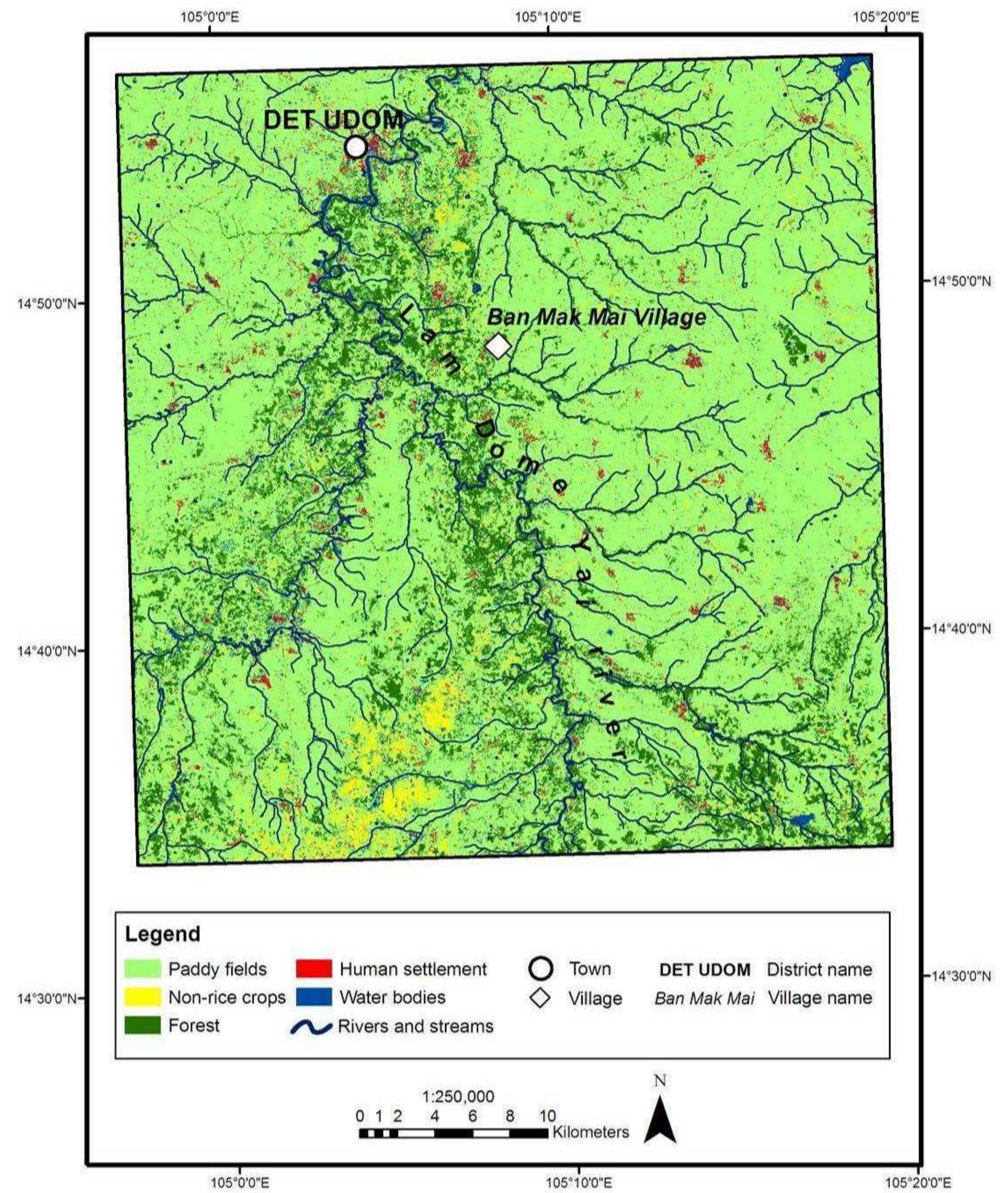
3.3.4. Promotion of Reforestation and Diversification of Agricultural Production Systems in the Nineties

In 1989, the logging business was banned and the “Green Issan” project was launched. Thanks to the new legitimacy of forest conservation, people were no longer allowed to encroach on forest areas. At the same time, reforestation was initiated by the Royal Thai Army. The aims were to plant commercial, fast-growing trees such as eucalyptus, and to conserve community forests. Perennial plantations like eucalyptus and cashew nut were promoted. Figure 3.10 shows less field crop area in 2002 compared to 1989, while more tree plantations are found in the northern part near Det Udom town. In addition, some field crops were converted into paddy fields in the southern part. Despite the declaration of the logging ban, deforestation in some parts continued, mainly through agricultural encroachment and the development of water resources sponsored by state agencies (The World Commission on Dams, 2000).

Because of the success of family planning schemes, demographic pressures on the land decreased. Economic policies increasingly became the determinants of changes in land use type. For example, the reform of the Common Agricultural Policy (CAP) of European Union (EU) in 1993 was particularly influential. This falling cassava demand greatly affected the exports of Thai cassava product since two thirds of the total production of cassava was exported to the EU before. The “Si Prasan project”, a joint-venture project between state agencies and private companies, was implemented in late 1987 to solve the problem of declining cassava prices by replacing cassava areas with cashew nut plantations. However, the project had very limited impact.

The failure of centralized water management by the state was disputed to effective water control during the severe 1992 drought, followed by floods in 1994. A long protest against the existence and negative impacts of the Pak Mun Dam ensued and dragged on for many years. These movements have been looked upon as a major turning point in water management (Chantawong et al., 2003). As a result, small-scale water infrastructure, in particular on-farm reservoirs, was extensively built in this area while rice still shared the largest portion of land (Figure 3.11). In recent times, the Thai government has been promoting Para rubber plantations in this region. This on-going project is likely to be adopted by large-sized farms because of its high investment costs.

Apart from economic incentives and infrastructure improvement driving changes in land and water use, the so-called “New Theory” of farming patterns has also affected northeastern farmers. This theory was initiated by His Majesty the King of Thailand to emphasize the self-reliance of farming units. The basic principle of this “theory” is the allocation of land to serve different household needs, with water as the most important component. “New Theory” types of APS (or “integrated systems”) have emerged and are now being promoted and extended throughout the country, especially in the northeastern region where poverty and water shortage are still serious problems (Jitsanguan, 2001). This theory was first introduced to Ubon’s farmers in 1984. However, its adoption is still limited because of inadequate water availability.



Source: Landsat ETM taken on 20 February 2002, Geographic Information System Center, Faculty of Engineering, Ubon Rajathanee University.

Figure 3.10 Land use map showing the five main land use types of the study area in 2002 based on supervised classification of Landsat ETM imagery.

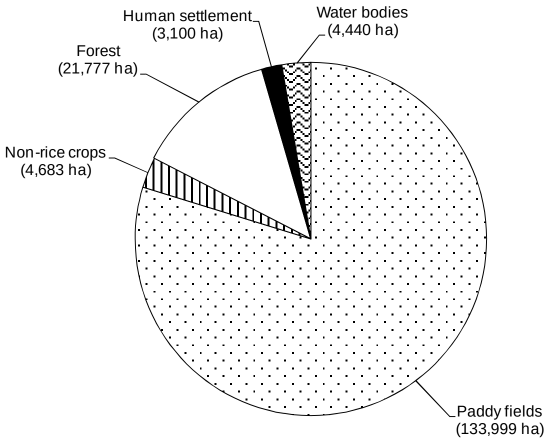


Figure 3.11 Five main land use types in the study area from a 2002 land use map.

Due to the Thai traditional inheritance system, whereby all children inherit land from their parents, an increasing number of small landholders has resulted in recent times. The number of workers working on large farms has become critical. These farmers have had to rely on agricultural machinery to alleviate labour shortages. Small holders are a source of labour for medium to large farming households. Well-off farmers have invested in more heavy equipment such as pick-up trucks and have used them to trade agricultural products between this community and cities. Tree plantations and fish production are now also found on large-sized farms.

Figure 3.12 shows the evolution of land use and land cover in the study area since 1973. Non-rice crops covered only 0.64% of the area in 1973 and reached their peak production at 7.18% of total area in 1988, dropping sharply to 2.79% by 2002 as a result of declining prices in the market. Meanwhile, rice-growing areas increased gradually, and forest cover quickly decreased from 1973 to 1989 in response to population growth and increased trade in timber commodities. Limited deforestation was seen in 2002 compared to the previous decades thanks to the ban on logging. As a result of water resource improvement, the area of water bodies increased from 1.5% in 1973 to 2.64% of the total area in 2002.

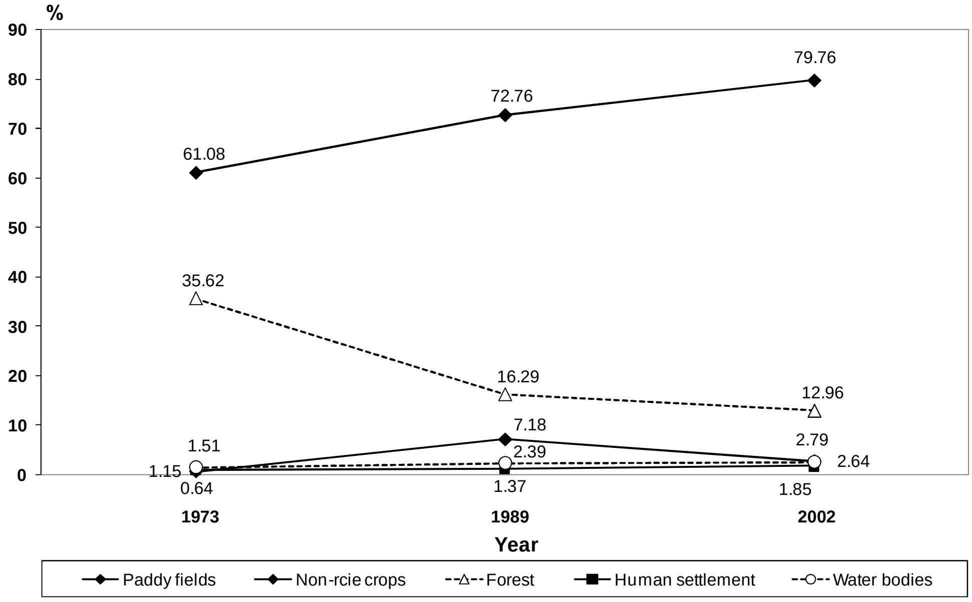


Figure 3.12 Changes of land use and land cover in the study area based on Landsat images taken in 1973, 1989 and 2000.

For these three decades, the people living in this area remained strongly attached to RLR production, even if the economic return was not adequate enough to meet their basic needs. Various strategies—such as diversification into annual, or more recently perennial, cash crops—have been used by community members to increase their agricultural output and secure adequate household incomes. However, for the majority of households who are small holders, labour migration has been perceived to be the most successful choice in reaching economic goals, even if they have had to leave their land and water underused, and put their children in the care of elderly people at home in the dry season.

CHAPTER 4
LABOUR MIGRATION IN LOWER NORTHEAST THAILAND AND ITS IMPACT ON FARMING PRACTICES

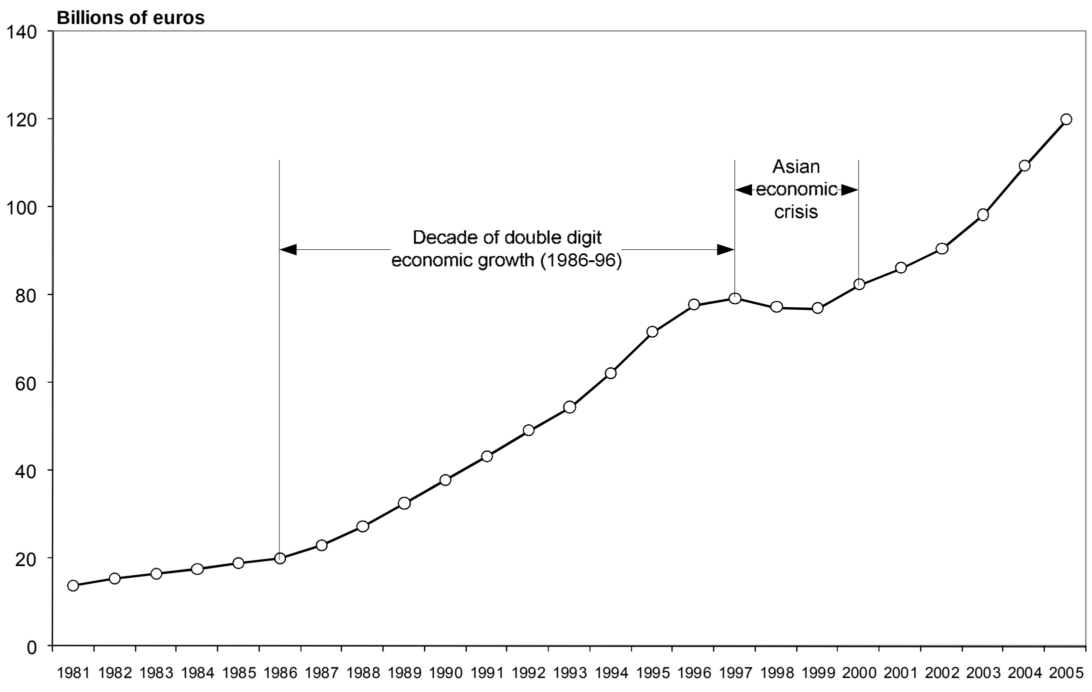
Farmers working in RLR ecosystems commonly use light machinery such as hand tractors, threshers and motorized water pumps. Investments in such machinery are made to alleviate labour scarcity in the production of rice. However, labour demand is always high during RLR transplanting and harvest. The labour required for these two activities can hardly be replaced by the use of farm machinery due to issues of limited accessibility that are caused by irregular small undulating plots with high bunds. Although the demand for labour is relatively high in the rice-growing season, most farm workers are rarely employed after the rice has been harvested. Consequently, many of them often migrate to work in cities. The availability of farm labour is generally determined by two key migratory patterns; these forms of migration can be classified as seasonal and more-permanent migration. Migration transitions have been closely related to Thailand's economic growth. From the 1960s, labour migration was seen as a social problem by many scholars, and this perception did not change until recently. This migratory evolution is important in understanding the migration decision-making processes that lead to changes in farming practices that alleviate labour scarcity when and where it occurs.

4.1. Transitions in Migrations in Relation to Economic Growth

Originally, the purpose of the repeated movements of the Thai-Lao ethnic group in the Korat Basin was to reclaim better land for RLR cultivation. Alongside Thailand's recent economic growth, these rural people, who were subject to out-migration, were perceived to be economic needy subjects that could supply cheap labour to the industrial and service sectors. From this economic perspective, three periods can be defined in relation to labour migration.

4.1.1. Before Rapid Economic Growth from Self-subsistent Systems to a More Export-led Economy

Before the late 1950s, RLR production in the northeast was managed by family labourers, mutual help through kinship networks, and the use of draft animals. Producing rice was mainly undertaken to satisfy family consumption. This subsistence economy still predominated throughout this region before national economic strategy shifted to export-led growth in 1982, with vast transportation development being a centerpiece of Thailand's fifth national economic development plan (Manarangsan, 2002). As a result of this change, the national GDP increased rapidly during the late 1980s and early 1990s (Figure 4.1). In the period between 1970 and 1980, rural-urban migration from the northeast region to Bangkok and the central plain increased by 21% (Richter, Chamratrithirong et al., 1990).

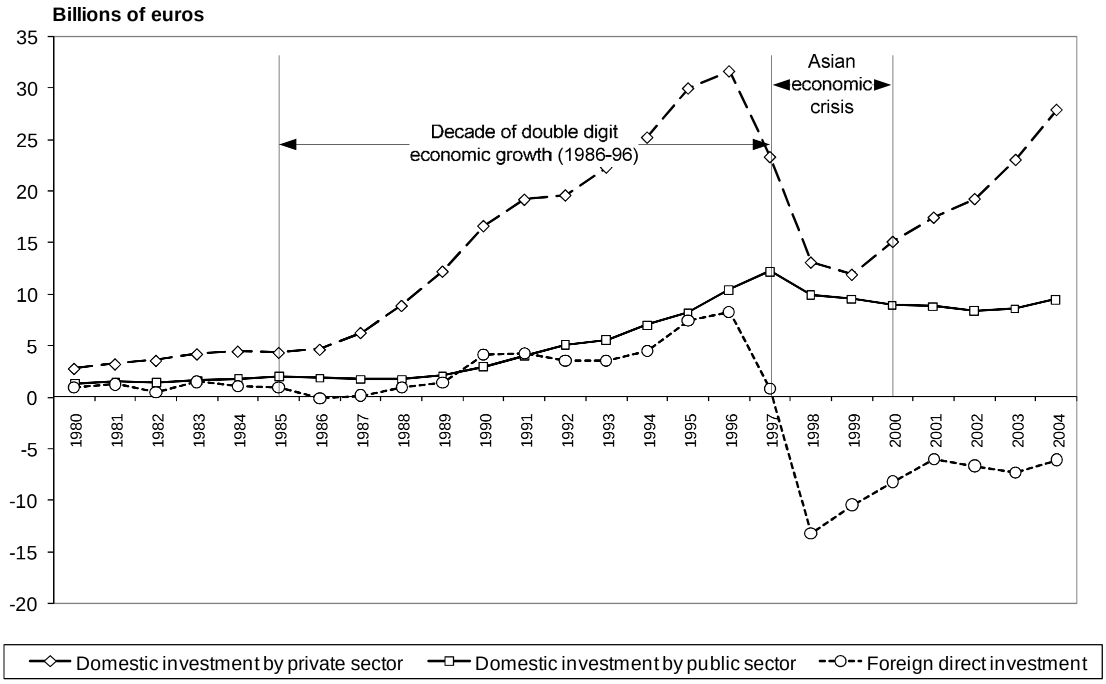


Source: National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

Figure 4.1 Growth of Thailand's Gross Domestic Product (1981-2005).

4.1.2. During the Rapid Economic Growth Decade of 1986-1996

Rapid economic growth resulted from massive amounts of direct foreign investment and the investments from the private sector facilitated by public investment in major infrastructure projects (Figure 4.2). By the late 1980s, low agricultural prices, land scarcity, and a growing population created the backdrop for massive rural-urban migration. In addition to these push factors, the expansion of industry and service sectors in Bangkok and its peripheral areas played an important role in pulling those migrants from rural areas (Matsumura et al., 2003). Low wages, progressive reductions in trade barriers, and years of conservative macroeconomic management resulting in low inflation and a somewhat stable currency exchange rate, attracted mega investment, especially from Japan, after the Plaza Accord (Siamwalla, Vajragupta et al., 1999).

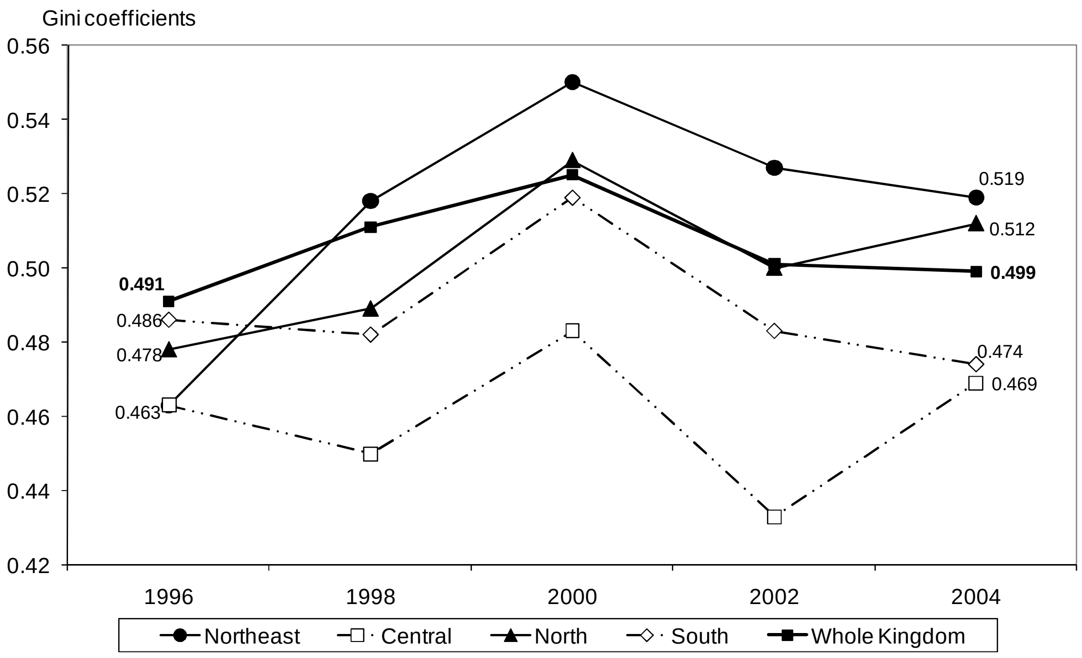


Source: National Economic and Social Development Board (NESDB), Bangkok.

Figure 4.2 Evolution of investment by sector in Thailand (1980- 2004).

However these investments did not benefit all regions equally, and regional inequalities and rural poverty rates increased over the period. The Gini coefficient indicates that the Northeast region suffered from this skewed income distribution

(Figure 4.3). Remittances generated by migrants is a way to transfer money from urban to rural areas in order to equalize income distribution at the national level (Skeldon, 1997). But this source of income is often underestimated or ignored because accurate data on remittances are extremely difficult to obtain, particularly in cases where there are exchanges in kind. The negative impacts could be seen at both the sending and receiving communities. For a sending community, the adverse impact of the social cost related to left-behind family members, and loss of development capacity due to an increasing number of more educated and younger migrant labours is prominent (Chantavanich and Risser, 2000). Overpopulation at a receiving community, which causes many social and economic problems, can be generated by the flux of migrants. For a migrant sending region like the Northeast, the problem of farm labour shortages leads to limitations in total agricultural output and the underutilization, or abandonment, of farm land. It also causes share-cropping, and the renting out of land (Paris, 2003).



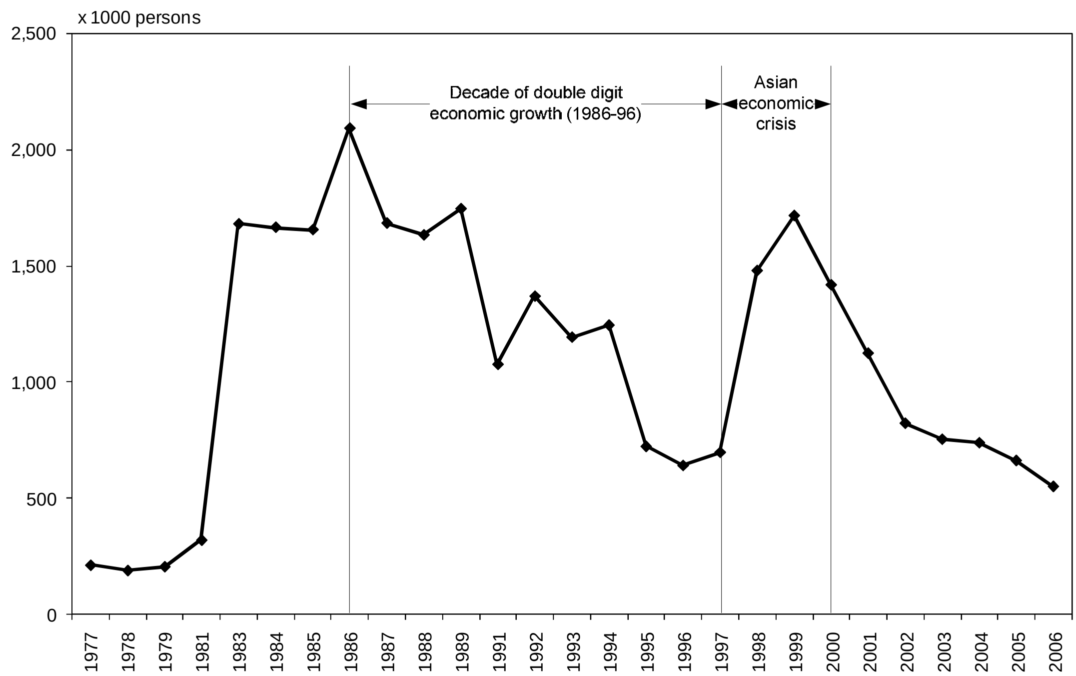
Source: Statistic Year Book 2006, National Statistical Office, Ministry of Information and Communication Technology, Bangkok.
Note: The Gini coefficient is widely used to display overall inequality in the distribution of income. It varies from 0.00, indicating perfect equality in income distribution, to 1.00, indicating a maximum degree of inequality.

Figure 4.3 Trends in income inequality by region indicated by the Gini coefficient Thailand (1996-2004).

The establishment of a securities market (SET), and a series of economic policy reforms to open Thai capital accounts, facilitated a rapid increase in short-term borrowings from abroad (Coxhead and Plangpraphan, 1998). The sudden outflow of these investments caused a major economic crisis affecting the labour market in 1997.

4.1.3. Thailand's Economic Crisis in 1997 and the Following Recovery Period

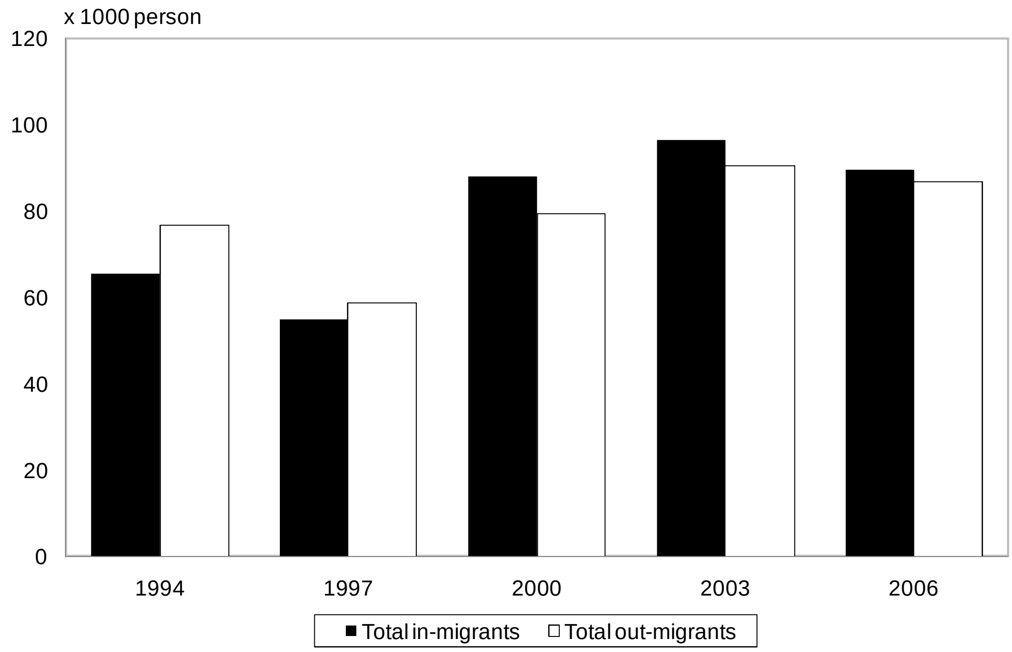
GDP decreased sharply in 1997 due to the lack of control on rapid capital outflow initiated by short-term borrowing from international money markets to finance the private sector. In June 1997, this massive capital outflow caused Thailand's, and more broadly, Asia's, economic crisis. A direct impact was rising unemployment, particularly in the non-agricultural sector. A labour force survey conducted by the National Statistical Office (2007) shows unemployment trends from 1977 to 2006 (Figure 4.4). Suhadhira (2004) estimates that "around 59% of the migrants returned to their northeast rural villages once the economic crisis occurred".



Source: National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

Figure 4.4 Unemployment trends in Thailand (1977-2006).

Changes in the numbers of in- and out-migrants for Ubon Ratcahthani province from 1993 to 2006 reflected this situation; the number of out-migrants became lower than in-migrants once the crisis took effect (Figure 4.5). But the rapid recovery of migration flows was seen again in 2000, and has since continued to the present.



Source: Department of Local Administration, Ministry of Interior, Bangkok.

Figure 4.5 Evolution of numbers of in- and out-migrants in Ubon Ratchathani province, Thailand (1994-2006).

Previous studies have shown that the most dominant migration stream over the last three decades was a ‘rural area to rural area’ pattern. But this migration stream became less prominent due to the decline in the availability of land (Goldstein, 1987), which has been considered an important factor stimulating Thai migration (Cochrane, 1979). Part of the flow to rural areas had been spurred on by a government sponsored resettlement scheme. Later, the migration stream changed to a rural-urban flow as a result of national policy that promoted export-led growth via the industrial and booming service sectors. These labour migration transitions explain the recent migratory context in relation to spatial and temporal mobility, as well as national policies implemented to deal with labour migration.

4.2. Recent Context of Labour Migration

Because the decision to migrate is a complex one, it is essential to understand labour migration patterns and potential migrant characteristics. Also, in this particular case, relevant migration policies launched by state agencies attempting to curb or redirect the migration flow need to be examined.

4.2.1. Definitions of Migration in Relation to Spatial and Temporal Dimensions

In Thailand, around 2.6 million people migrated between regions in 2002 in search of off-farm and non-farm employment (National Statistical Office, 2002)F. Labour migration in this study refers to the mobility of people seeking employment by crossing the provincial boundary from a place of origin (residence) to a place of destination, and staying there for longer than five months. It is necessary to refine the classification of migratory patterns by integrating this spatial movement with its temporal dimensions. A suggested typology of migrations proposed by Kok et al. (2003) has been adjusted to present existing migratory patterns found in Thailand and is presented in Table 4.1.

Table 4.1 Typology of spatial and temporal migrations encompassing circulation and permanent mobility**.**

		Temporal dimension		*Spatial dimension*		
Broad category	*Example*	*Description*	*Change in place of residence?*	*Description*	*Migration defining boundary crossed?*	*Classification*
Circulation	Daily work trips	Short-term circular moves with no change of residence	No	Short distance moves	No	Daily commuting
	Return to place of residence to work on the migrants' farm in particular during rice-growing season and migrate to work at the place of destination when rice-growing season ends	Short-term circular moves that do not necessarily involve a change of home address but involve a change of place of residence	Yes	Long distance moves	No	Local weekly commuting
					Yes	**Short-term seasonal migration**
	Labour absences from home: usually return home only for visiting and return to place of employment after a period of stay at the origin	Long-term circular move. A move taking place at the beginning or end of an extended migrant-labour period	Yes	Long distance moves	No	Local long-term labour mobility
					Yes	**Long-term more-permanent migration**
Permanent move	New family settlement	Short or long-term residence at place of destination	Yes	Short or long distance moves	No	Residential mobility
					Yes	Permanent migration

Source: Adapted from the typology of spatial mobility by Kok et al., 2003.

In particular, two patterns—short-term seasonal and long-term more permanent labour migration— are emphasized in this study because they strongly influence the fluctuation of available family farm labour at places of origin at my study site. In my case, permanent migration becomes irrelevant since a family usually prepares itself to encounter permanent labour change, and therefore discontinues its farming activities. In this study, all analyses regarding labour migration refer to a place of origin and destination of specific migratory moves within the country. It is often defined as interregional labour migration, which is the dominant migration stream in northeast Thailand (Chamratrithirong, Archavanitkul et al., 1995). All forms of forced or compulsory migrations are excluded in this study.

4.2.2. Characteristics of Potential Migrants in Relation to Migratory Patterns

According to the Migration National Survey (Chamratrithirong et al., 1995), the definition of a potential migrant is based on demographic characteristics, education, and current occupation. Migration peaks at the age of 20-24 for both men and women, but this peak largely reflects the single-move migration pattern, usually a result of a new family settlement or education. Seasonal migration is fairly constant for men aged 15-34 and women aged 15-24. These periods indicate that men are more likely to migrate than women, especially in terms of short-term moves at older ages. This may be due to childbearing and increased family responsibilities among women aged 25 and over.

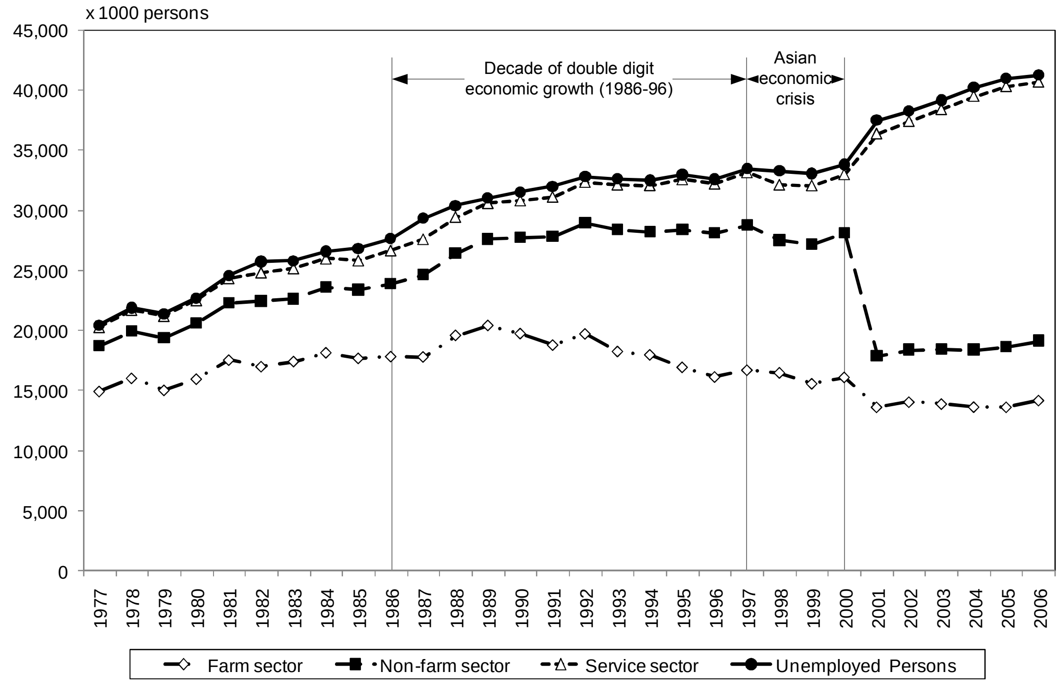
Married men are much more likely to migrate seasonally. Persons living with their spouse are less likely to migrate, especially for women; however, men undertake a fairly high rate of seasonal migration. Unmarried men and women have stronger intentions to migrate. A person with an education greater than primary school level is likely to be a more permanent migrant because they are perceived to be more highly skilled workers; non-farming economic sectors demand their labour. Most seasonal migrants are marginal and small farmers at their place of origin (Paris, 2003).

Beyond internal characteristics, external socio-economic factors also potentially motivate labour migration. Both men and women migrating to cities are often driven by the need for additional income in order to send remittances and because of unavailable job opportunities at their place of residence. Social contact at destination is a determinant in the facilitation of the eventual movement to the destination. In the Thai context, migrants often find employment and lodging near, or with, relatives and friends for better accessibility to information and sponsorship (Fuller, Lightfoot et al., 1985). Experienced migrants play an important role in attracting and facilitating new migration flows between sending and receiving regions.

4.2.3. Migration Related Policies and Direction of Interregional Migration at the National Level

Migration-related policies in developing countries usually aim toward limiting the volume of movement (Skeldon, 1997). By and large, labour migration itself can act to alleviate poverty in the rural sector. Policies aimed at restricting population migration may be counterproductive and not in the best interests of the rural poor. In the context of Thailand's economic growth, many rural dwellers were encouraged to work in non-farm economic sectors, causing a rapid transfer of labour from agricultural to industrial and service sectors (Figure 4.6). To keep wages low, a key comparative advantage of the country in modern, competitive international markets, Thai governments managed to keep the price of staple foods at affordable levels for these labourers. Such state policies became a bedrock of labour migration in this country (Richter et al., 1990).

Concerns around the issues of migration were prominently addressed in the fourth national plan (1977-1981). The main concept was to redirect migrants to intermediate-sized towns, in accordance with a growth-pole strategy. However, the evaluation of this policy showed that this strategy was not successful. There was little impact on the reduction of migrant volume to Bangkok because disparities in regional incomes and job opportunities between Bangkok and designated regional hubs, such as Khon Kaen and Nakhon Ratchasima provinces, were still too large (Ad Hoc Sub-Committee of Population, 1981; Matsumura et al., 2003). Moreover, the mismatches between the demand for educated and skilled labour in these regional hubs impeded such a move by many unskilled or semi-skilled workers originating from the northeast region (Feeny, 2003).



Source: National Statistical Office, Ministry of Information and Communication Technology, Bangkok.

Figure 4.6 Labour force working in three main economic sectors in Thailand (1977-2006).

Some business interests have also encouraged workers to seek overseas employment, and following the Asian economic crisis, this became a government policy. One reason for promoting overseas work has been to increase the level of remittances (Hewison, 2004). However, this policy has a serious drawback in that it may cause increased indebtedness of these potential migrants. People who invest their money through a job broker often encounter the risk of being exploited. This situation was illustrated by a renowned Thai lawyer, Thongbai Thongpao, in the following newspaper article:

Farmers face collateral damage

Like the majority of the people in Thailand, the residents of Ban Koyang, Prasart district, Surin Province, lower northeast, earned just enough to get by but not enough to improve their way of living in a substantial way due mainly to droughts. In 1986, Suchai, a local rice farmer, was convinced by the light at the end of tunnel. Seeing his neighbours who went to work aboard were able to send home hefty paychecks, Mr. Suchai decided to follow suit through a job broker in Surin Province. The commission of 40,000 baht was demanded. His family had to pledge the land as collateral against such amount of money. After a year Suchai never got sent to work aboard. He reported the job broker to the police and a public prosecutor filed a lawsuit with the Surin court against the job broker for violating the Job Seeking Act. In 1994, the Surin court found the job broker guilty as charged but an appeals court later reversed the ruling and dismissed the case.

It turned out that the job broker used his land title, as well as of others, as collateral to borrow from Krung Thai Bank around 200,000 baht at an interest rate of 15 percent per year. Under the loan contract, if the job broker failed to repay the debt, Suchai's land could be seized and put up for sale to repay the debt. As can be expected, Suchai had no way of repaying such a huge sum and his land, as well as of others, was finally seized and will be put on the block at the end of this month. And it is quite imminent that land put on the block is generally snatched up quickly at a very low price by wealthy people, to be returned to farmers or resold for a handsome profit. The same thing is happening all over the country, in direct challenge to government's asset-capitalization policy and war against poverty.

Bangkok Post, 15 May 2005 by Thongbai Thongpao

Previous policies to manage labour migration have not been successful because the motivation to earn an income, and the perceived lure of job opportunities at industrial sites around Bangkok and the Eastern Seaboard, is still high. Moreover, the migratory behaviour of former and potential workers shows that they always look for a job in places where they have worked before, or where their relatives and friends are present. Therefore, the labour outflow from the Northeast remains unchanged. To better understand this labour flow, it is essential to look closely at the migration decision-making process.

4.3. Migration Decision-making Processes

Several studies have exclusively examined and modelled the cause-effect relationship of migration through the lens of economic incentives and disincentives. It has been suggested that economic factors are the root causes of migration. However, the decision to migrate is a complex process dealing with multiple factors. Economic determinants only are not enough to completely explain this process. But these economic-based migration studies have provided a foundation in the formation of later migration theories integrating non-economic determinants.

4.3.1. Migration Models Based on Economic Factors as a Cause of Action

The neo-classical school of economics, or equilibrium, model suggests that migration is caused by geographic differences in labour supply and demand, and by the resultant wage differentials (Kok et al., 2003). According to this theory, an individual migrant makes his decision based on an assessment of such differentials as push and pull factors. Unlike neo-classical economics, the new economics of migration suggests that migration decisions are seldom made by isolated individuals (an assumption central to the micro-economic perspective), but rather by families. In the northeast, the decision about migration usually involves all family members (Hewison, 2004; Richter, Guest et al., 1997). In order to self-insure themselves against income, production and poverty risks, or to gain access to scarce investment capital, households send one or more workers into the labour market (Chantavanich et al., 2000). The shortcoming is that this model does not preclude migration to areas with a minimal or negative wage differential. Moreover, it is seen to simply assume that all individuals within a household have the same interests.

The neo-classical and the new economics models view migration as a rational calculation process of individuals and families in response to the labour market. Segmented or dual labour market theory considers the economic structure of highly industrialized regions as a pull factor of migration (Kok et al., 2003). This theory states that labour migration is demand-driven, since the demand for migrant workers results from the structural needs of the industrial economy, while wage differentials are neither necessary nor sufficient for labour migration to occur.

Historical structural theory addresses the historical economic development of any receiving region, determining its present economic structure; it is the present economic structure which creates conditions for migration. (Baldwin-Edwards, 2008). Economic factors perpetuating migration can be found in migration system theory (Massey, Arango et al., 1993). This theory examines all dimensions of the relation between emigration and immigration regions. It recognizes the close links between flows of people, capital, commodities and technology from less intense and stable areas to relatively intense and stable ones. This model encompasses the whole migratory process. It combines many existing approaches in order to create a more comprehensive and inclusive model of migration study.

The Thai cultural context, the sets of interpersonal ties connect migrants, former migrants, and non-migrants, in both origin and destination areas, through ties of kinship, friendship, and shared communities of origin (Chamratrithirong et al., 1995; Massey et al., 1993). Making migration decisions depends on their (or their relatives' or friends') migration experience, their social connections with other migrants, and their households' collective input into the decision making process itself. This leads to another theory, culture of migration; the theory states that as a result of the knowledge and experiences gained from the first migratory attempt, people are likely to migrate again (Chantavanich et al., 2000). Even if these social networks seem to take non-economic parameters into account, key reasoning behind the migratory move is still driven by economic differentials.

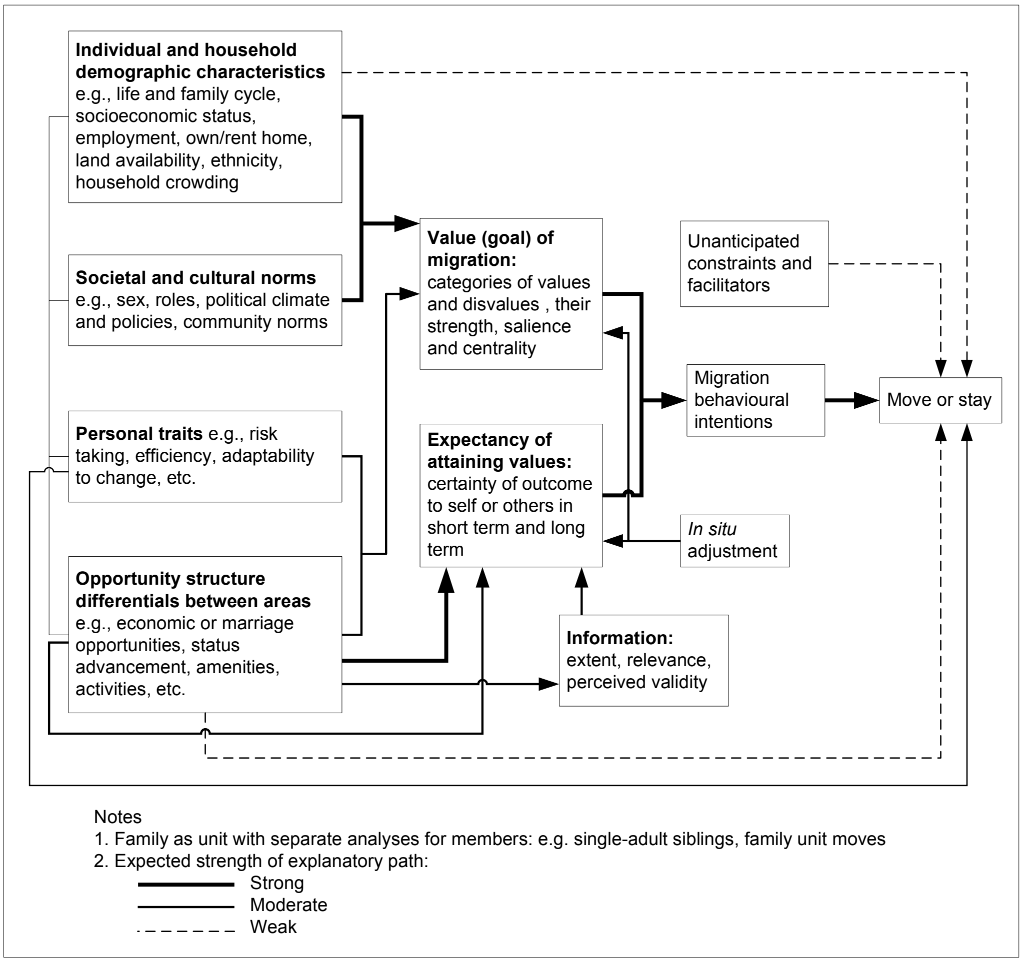
A drawback in applying these macro economic- or social network-based theories is that migration is considered an independent variable, which not only regulates other societal changes, but controls itself (Kok et al., 2003). In this study, it is important to understand that the migration decision-making process involves interactions between economic and non-economic factors, essentially occurring at micro (household or individual) level.

4.3.2. Model of Micro-level Migration Decision Making

While macro and aggregate models of migration provide broad perspectives for the planner, the micro approach offers more insights by focusing on the decision-making behaviour of individuals (Hoong and Chang, 1981). Motivations are the basic elements of a micro-level theory on migration decision-making. These motivations are usually goal-driven and often refer to personal or situational strength of goal-oriented behavioural tendencies (De Jong and Fawcett, 1981). Besides, macro factors can be examined at a micro-level by integrating these factors into individual decision-making processes (Gardner, 1981). A particular approach, called the Value-

Expectancy (V-E) model, is proposed to represent migration behaviours. The V-E model has been empirically used to study migration decision-making in many developing countries, including Thailand, by De Jong (1997; 2000; 1981) and Gardner (1981). These authors have shown that the important causes of migration at both micro and macro levels operate indirectly through people's values and expectations.

The V-E model is derived from cognitive theories and decision-making approaches in psychology, aiming at a better understanding of how individuals evaluate their residence in relation to personal needs, values, and aspirations (Figure 4.7). The concept is based on a combination of goals that people have in mind and expectations that one wishes to achieve if they decide to stick to their goals.



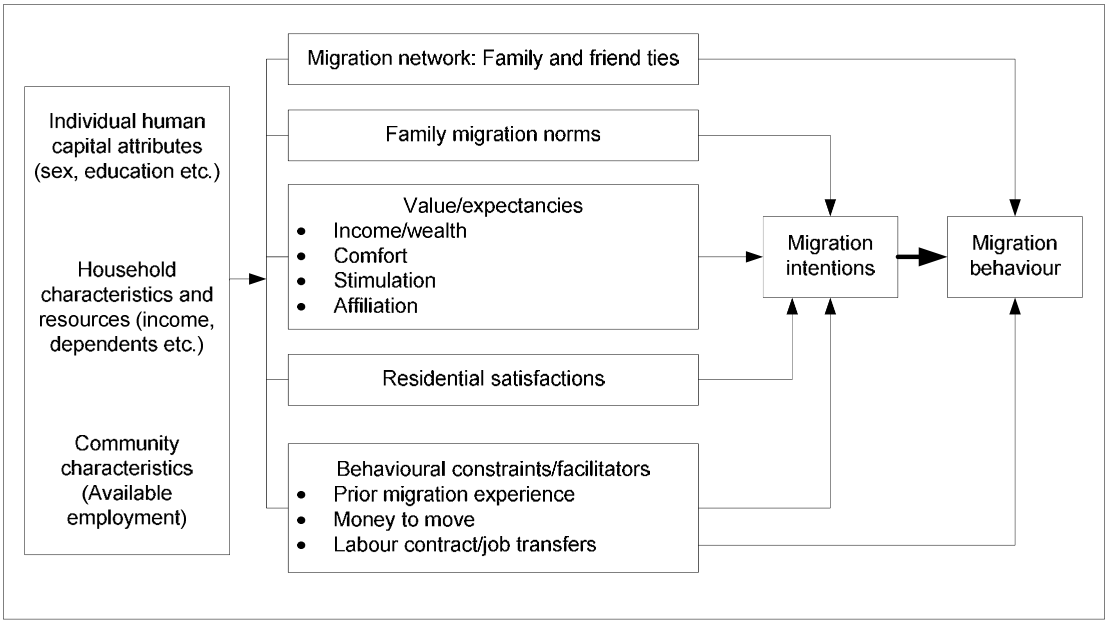
Source: De Jong and Gardner, 1981.

Figure 4.7 The Value-Expectancy model of migration decision-making.

Pairs of the value-expectancy components have a multiplicative relationship for specific items, and the products are summed over all the items being considered in order to obtain the strength of migration behavioural intentions. Individual and household demographic characteristics are the most often mentioned factors determining migration behaviour. These factors can be used to summarize the compositional thesis of populations, some with higher and some with lower propensities to move, which explain why certain areas have higher migration rates than others (De Jong et al., 1981). Societal and cultural norms have similar impacts on migration decision-making as the demographic characteristics. Personal traits are another set of predictors for values, expectancies, and migration. However, the influence of personal traits, and societal and cultural norms, on migration decision-making is difficult to measure satisfactorily.

The differentials of opportunity structure are keys in generating expectancies for attaining goals in the place of origin compared to alternative destinations. In my case, the differential on economic opportunity plays a key role in the expectation for a better livelihood. With this approach, linkages between macro-level indicators and micro-level V-E dimensions can readily be postulated and tested (De Jong et al., 1981). Information about areas is seen as a factor that moderates the effect of opportunity structure differentials. Unanticipated constraints and facilitators may refer to abrupt change in the family structure (e.g., death of spouse, divorce, or marriage) or change in other factors such as the cost of moving. Constraints and facilitators (especially the unexpected ones) intervene between intentions and the decision to move or stay. In situ adjustment mainly indicates the causes of staying rather than moving. Migration is a purposive behaviour in which the potential migrant first makes a conscious decision on whether or not to migrate through a process by which perceived consequences are weighed and evaluated. Then a second decision is made regarding the choice of destination.

The V-E model is built to represent individual migration decision-making by integrating micro-level with macro-level determinants into the same model. In 2000, De Jong developed a general model of migration decision-making based on the V-E model and used it to study migration in Northeast Thailand (Figure 4.8). In this model, migration intentions are a primary determinant of migration behaviours, along with migration networks, and behavioural constraints and facilitators. The values/expectancies of attaining important life goals in the rural villages compared with Bangkok, along with family migration norms, behavioural constraints and facilitators, and residential satisfactions are direct determinants of migration intentions.



Source: Adapted from De Jong's general model of migration decision, 2000.

Figure 4.8 General model of migration decision-making.

Among the value/expectancies, the income/wealth variable plays a crucial role in determining migration intentions in the case of northeast Thailand. Local residents with low income expectancies at their place of origin and less satisfaction with work opportunities have greater intentions to migrate. The comfort, stimulation and affiliation associated with the value of the living environment have a weak influence on migration intentions because essential facilities, such as schools and public health stations, are sufficiently provided in, or nearby, villages. Also, friends and family at the place of origin do not strongly influence the intentions to migrate because of better communication and transportation. In contrast, friends and family at a place of destination, who provide a source of information and sponsorship, are always positive factors in the increase of migration intentions. The presence of children or elderly dependants is an important family norm that affects migration decision making differently according to gender. This family norm increases migration intentions for men but reduces them for women because they are usually asked to look after these dependants.

Because rural Thai migration behaviour is subjected to family control, women tend to work in villages and have low opportunities to migrate from their families. Thus, among the behavioural constraints and facilitators, prior migration experience is a highly significant predictor of future intentions for women but not for men. None of the household resources or community characteristics significantly related to changes in migration intentions, except community crop loss, which is positively related to migration intentions. The individual capital attributes regarding demographic characteristics (e.g. marriage, age and gender) are important determinants of family migration norms, while education, wage differential, and migration experience are considered to directly influence the migration intentions.

Value-expectancy and residential satisfaction are important predictors of migration intentions; they are significant predictors of more-permanent, but not seasonal, rural out-migration behaviours. Individuals with high migratory intentions are commonly skilled workers with migration experience, and have social networks at places of destination. These migrants are likely to have more secured working conditions. Low household income has a higher direct effect on seasonal migration than on more-permanent migration.

This general model takes into account both economic and non-economic causes of migration with the integration of V-E model to include individual, household and societal determinants of migration. It is a comprehensive migration model that has been tested with migrants from Thailand's northeast. Moreover, this model focuses on the migration decision-making processes of individuals, which is appropriate for the purpose of representative modelling of heterogeneous stakeholders. In this study, an individual having its specific characteristics (e.g. age, gender, marital status, education, and prior migration experience), and evolving over time, is a central migration decision-maker. Such an individual's migration intentions are modelled to represent consequences of the interactions between its characteristics and other components at household (migration network), and community level (employment availability). Then, the outputs of migration intentions (high, low or no intention) are used in relation to household income and presence of family dependants to determine the migratory pattern (seasonal, more-permanent migration, or stay home) of the individual.

Because the migration of local farmers is closely related to possible labour shortage on farming households, new farming practices have emerged to cope with this problem.

4.4. Change in Farming Practices in Relation to Labour Migration

Although the northeast of Thailand is the largest rice-producing region in the country, the production still largely depends on human power. Therefore, a lack of farm labour has resulted in the emergence of new farming practices, which have been adopted by rice farmers to cope with labour scarcity. General migration impacts on both sending and receiving communities should also be mentioned.

The lack of labour during high demand periods such as RLR transplanting and harvest have resulted in the introduction of new farming practices adopted by rice farmers to cope with labour scarcity. The loss of male labour may result in the decline in farm production where only females and small children are left to look after the farm. But remittances can be spent on the farm to compensate for the loss of labour through the employment of hired farm workers for example (Shinawatra et al., 1996). On farms where the share of remittance income from relatives employed in cities and aboard is increasing, income from rice farming is becoming relatively unimportant. Such remittances are often spent on consumption, home improvement and education, while only a small portion is invested in farm production (Deshingkar, 2004).]

Changes in farming practices in relation to labour migration depend on the type of RLR management determined by the land per labour ratio. In the case of high land-labour ratio at an average of 1.9 ha per unit of labour, labour shortage is a major constraint. Well-off farmers often invest in machinery to replace human labour, but this is not feasible for RLR transplanting due to a lack of water control; moreover, the use of machinery at harvest is still limited to threshing. Combined harvesters are used in the western part of lower northeast Thailand but not in Ubon Ratchathani as yet. Farmers also grow two or more rice varieties with different durations so that they are able to better manage labour at harvest. Some farmers have also adopted the direct sowing technique for RLR establishment, instead of the labour intensive transplanting one. Few farmers downsize their planted areas by renting-out their paddies. But such practices to cope with labour scarcity usually operate alongside the additional hiring of labourers. Thus, the availability of labourers for hire in their community still plays a crucial role in local rice production.

In the case of low land-labour ratios, ranging from 0.6 to 1.6 ha per unit of labour, a key strategy on such small holdings is to increase labour productivity through on- and off-farm employment, including migration. Many farmers adopt integrated farming systems combining diverse productions (rice, fruits, vegetables, fish etc) at a small-scale around a farm pond to meet family needs and generate a small surplus for sale. Smaller numbers rent more land to grow rice. A frequent practice to get more cash is to accept off-farm employment on larger neighbouring farms during RLR transplanting and harvest.

To facilitate the representation of these different land and labour management strategies and practices in a model, the construction of a farmer typology based on the different socio-economic objectives and management strategies of a few types of farms is a useful tool.

CHAPTER 5

ANALYSIS AND CLASSIFICATION OF FARMING HOUSEHOLDS, AND THE IMPORTANCE OF LAND & WATER AND LABOUR INTERACTIONS

As the understanding of on- and off-farm decision-making processes is paramount to explain local RLR management practices the diversity of APS needs to be taken into account. However, it is very difficult to do so because all farms are different. Nonetheless, a holistic view of these farming systems can be taken in order to analyze the functioning of APS by focusing on interactions between local agroecological and socioeconomic dynamics; from this approach, a farmer typology can be adopted. Essentially, a comprehensive knowledge of APS functioning in their diversity and their classification into a farmer typology is necessary in the initial conceptualization stage of my modelling process; moreover, it is important in the selection of participating farmers.

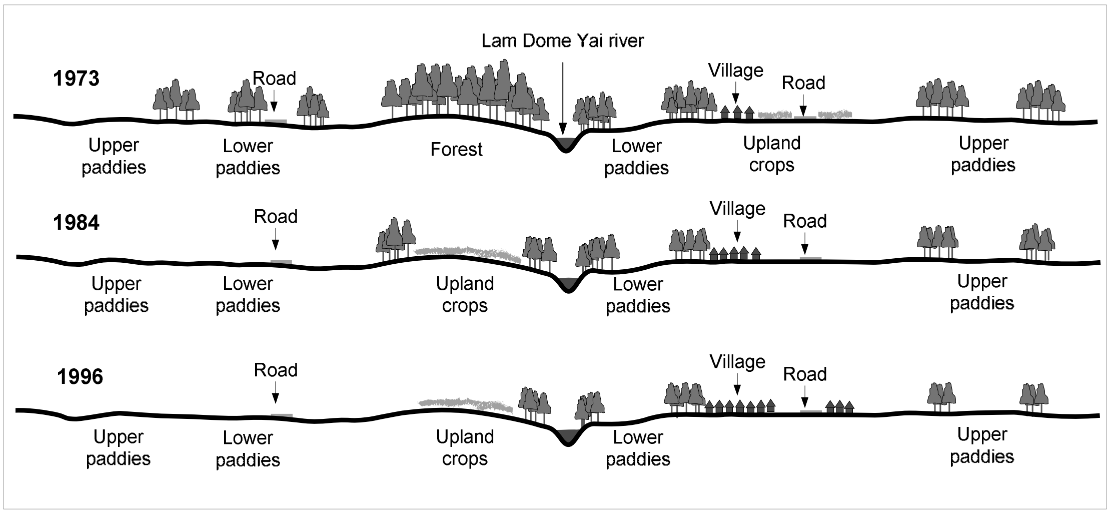
An APS is defined as the whole structured set of plants, animals, and other activities selected for production by a farmer to achieve his or her objectives (Trébuil and Dufumier, 1993). APS analysis enhances my understanding of the system and problems at stake. The goal of this analysis is to group farmers into a limited number of types according to similarities in their socioeconomic objectives/goals, and strategies to achieve those goals through a reliance on an agro-ecosystem and specific means of productions.

The sample of farming households analyzed in 2003 was the same sample used in two previous studies conducted at this site in 1994 and 2000. Twenty farming households were selected to cover the broadest diversity of cropping and animal rearing systems presented at the study site. This extensive diversity within the sample is required to uncover the different objectives and strategies of the various types of APS (Trébuil, Kam et al., 1997). In 2004-2005, two farm surveys with semi-structured guidelines were carried out to gather data on the different main types of household-based APS and to examine the determinants of labour migration among these different categories of farming households.

The second farm survey carried out in April 2005 specifically addressed the relationship between labour migration and the serious drought of the 2003 crop year (Naivinit, 2005; Naivinit and Trébuil, 2004). Based on this knowledge, diagrammatic representations of APS were produced to illustrate the relationships among farmers' objectives, strategic APS management practices, and means of productions. Then, based on the comparison and identification of similarities and differences between these APS functioning diagrams, several main types of farmers were defined into a typology.

5.1. Characterization of Main Combinations of Productions on Agricultural Production Systems

Recent agricultural transitions in the study area, where the mini-watershed is the dominant landform, has seen the forest cover decrease and be replaced by upland crops such as cassava and long fibre crops (Figure 5.1). But rice is still the major crop. The growth cycle of rice is central in determining other on-farm and off-farm activities. Three main combinations of productions were found in this village.



Source: Aerial photographs taken in 1973, 1984 and 1996 by Royal Thai Survey Department, Royal Thai Army, Ministry of Defence, Bangkok.

Figure 5.1 Land use change along a transect in Ban Mak Mai village, Klang sub-district, Det Udom district, Ubon Ratchathani province (1973, 1984, 1996).

5.1.1. Rice-based Systems with On-farm and Off-farm Employment Including Labour Migration

The majority of APS found in this village belongs to this category. Rice production is first and foremost done for family consumption and to sell any surplus. This rice-based system often lacks the production of crops other than rice, due to limitations related to irrigation and inadequate cash reserves for the diversification of farm production. Furthermore, additional income can be, and is, generated by means of labour migration. Rice production is usually managed by family labour, which employs transplanting techniques. There are small vegetable plots for family consumption near the house. Livestock rearing is rarely seen.

Because of very small land holdings, debt burdens, and lack of local employment alternatives in agriculture, farmers working in exclusively rice-based systems commonly migrate to search for more profitable employment in cities during the dry season and between periods of transplanting and harvest.

5.1.2. Rice-based System with Diversification out of Rice

Non-rice productions are found in this kind of APS. Rice is commonly produced in lower and upper paddies, while cash crops such as cassava or perennial plantations, such as cashew nut, are grown in upland areas. The type of perennial cash crops grown is often promoted by the government, and some of them are supported by private companies offering price support programs, as has been the case of cashew nut plantations. Cattle and buffaloes are also raised for sale. Well-off farmers often invest in fish farming and fingerling production. The use of more farm machinery is being seen on large farms to alleviate labour shortage.

In the last decade, Para rubber, which was promoted as a new perennial cash crop for the northeast region, has extensively replaced annual cash crops and eucalyptus because of their higher economic returns. Nonetheless, it was not rapidly adopted by poor farmers due to a lack of funds to cover the initial high investment, longer harvesting times, and a lack of skill needed to work with such plantations, compared to other traditional cash crops (Phupak and Theerapongtanakorn, 2006).

5.1.3. Rice-based Systems with Integrated Farming

Since 1995, the northeast region has been the target of both government and non-government organizations for the promotion of integrated farming systems, an alternative to seasonal migration for off-farm employment (Wigzell and Setboonsarng, 1995). Integrated farming is defined as a household-based APS with a diversity of complementary agricultural productions to enhance the efficient use of limited resources (Faculty of Economics Kasetsart University, 2000). The aim of integrated farming is to assist farmers in producing for home consumption and a surplus for sale, according to the principles of the “sufficiency economy” (Mongsawad, 2007).

Rice is still the main crop produced for family consumption and sale. Other cash crops and vegetables are grown near water resources, which are also used for livestock rearing. Thus, reliable water availability is central to integrated farming. Small water retention programs have been carried out to support the construction of individual farm ponds. However, changing from conventional to integrated farming still requires substantial investment, with farmers reaping benefits from such investments only after a few years. This has caused the slow diffusion of integrated farming practices among relatively poor farmers. Despite the proof that farmers adopting this system have become more self-reliant, the evidence gathered so far suggests that integrated farming has had only a limited impact on labour migration.

5.2. Farmer Typology at Study Site

Based on the above-mentioned main combinations of productions, three kinds of APS were identified, forming the basis of a farmer classification system, or typology; moreover, the farmers’ socio-economic objectives, strategic choices of farm and non-farm practices, and means of productions were also integrated into the farmer typology. These farm types represent the diversity of farming households in the study area (Table 5.1).

5.2.1. Farm type A: Very Small Rice-based and Subsistence Oriented Farms

The farmers’ main constraints in this category are high indebtedness and the very small size of their land holdings, ranging from 1.6 to 4.8 ha (3.2 ha on average). Their objectives are to produce enough rice to meet family food requirements (in rice first) and make cash income through the sale of rice surpluses, and the full employment of family labourers. Almost 70% of local farmers belong to this farm type. These very small farms evolved from the medium-sized rice-based farm holdings (4-6 ha) with limited off-farm activities found in 1994 (Table 5.2).

Table 5.1 Characteristics of the three main types of farmers in Lam Dome Yai watershed, Ubon Ratchathani province (2004).

Type	***A:** Very small rice-based and subsistence oriented farms*			***B:** Medium-sized rice-based and integrated farming, more market-oriented farms*		***C:** Large market-oriented farms with diversification out of rice or high remittances*	
Farm size (ha)	1.6 - 4.8			4.8 - 9.6		8 - 19	
Family size (person)	4 - 6			5 - 7		6 - 8	
Farmed area per family labour (ha/labour)	0.64 - 1.6			2.2 - 4		1.7 - 2	
Objective	Family staple food security and income through selling surplus aromatic rice and full employment of family labour			Produce non-glutinous aromatic rice for sale and increase land productivity through integrated farming		Increase labour productivity through diversification out of rice	
Strategy	• Motorized farm equipment is used for land preparation and water management. • Late-maturing non-glutinous (KDML105) rice for sale • Early-maturing (traditional glutinous) rice for family consumption • Cattle and buffalo are raised and sold when cash is needed • Fish and poultry is for family consumption and sale. Off-farm employment is important source of income to support on-farm activities.			• Late-maturing (non-glutinous, KDML105 and glutinous, RD6) rice for sale, • Early-maturing (traditional glutinous) rice for family consumption • Hire l labourers to harvest late maturing rice • Products of integrated farms for family consumption and sell surplus • Livestock is raised for savings and sale		• Late-maturing (non-glutinous, KDML105 and glutinous, RD6) rice for sale • Early-maturing (traditional glutinous) rice for family consumption • Use farm machinery e.g. hands tractors, rice threshers to alleviate family labour scarcity	
Sub-types	**A1:** • Low access to water • Migrate seasonally for non-farm employment • Receive low remittance	**A2:** • Poor access to water • More-Permanent off-farm labour • Receive medium to high remittance	**A3:** • Good access to water • Migrate seasonally for non-farm employment • Receive low remittance	**B1:** • Good access to water • More-permanent off-farm labour • Relative high remittance	**B2:** • Very good access to water • Raise livestock for sale • No migrants	**C1:** • Upland crops e.g. cassava • Plantation crops e.g. cashew nut, para rubber • Fish production to maximize labour productivity • No migrant	**C2:** • Large rice-based farms • Permanent off-farm employment or entrepreneurs in village • More-permanent off-farm labour • Relative high remittance
Volume of water stored in ponds (m^3)	170	450	1950	2160	2400	4500	
Investment capacity	Insufficient			Limited due to debts		High	
Average annual gross income (euros)	1,150 (min: 400 - max: 1,600)			2,100 (min: 650- max: 2600)		4,900 (min: 1,700 - max: 7,700)	
Share of off-farm income (%)	66 (min: 50 - max: 71)			22 (min: 0 - max: 31)		6 (min: 0 - max: 29)	
Share of Debts (% of annual gross income)	31 (min: 25 - max: 57)			31(min: 17 - max: 46)		4 (min: 0 - max: 6)	

Farmers belonging to this type play an important role in supplying labour to larger holdings because their land per labour ratio is low. Even if the harvesting time of the famous aromatic jasmine rice, KDML105, is the same for all farms, they finish their own harvest sooner and subsequently sell their labour to larger holdings. However, the share of farm land planted to KDML105 and glutinous rice is determined by the family consumption requirements, which needs to be met first (highest priority). If the family consumption is secured by an adequate amount of stored glutinous rice, these farmers are likely to plant a higher share of glutinous rice and KDML105 to increase their household income, especially when rice prices are high, such as in the 2008 wet season.

Livestock is rarely raised on this farm type. If it is present, the herd is small (2-5 heads) and the purpose is mainly for savings. Access to water is another factor determining the RLR cropping calendar, but not the choice of non-rice productions. However, water use is carefully managed since the purpose of having small ponds is to store water and use it to water RLR nurseries in case of dry spells. Rice is always the major crop even if the land is located in upper paddies where water is even less accessible. A way to increase their on-farm labour productivity is to rent more farm land. The rental payments can be made in cash or in the form of a sharecropping arrangement.

The farmers' capacity to make investments is none to very limited, and indebtedness is high. Off-farm, including non-farm, employment is a very important source of income. More permanent and seasonal labour migrations are key strategies used to cope with financial difficulties. But it is risky to rely mainly on migrant labour because most of the workers are unskilled, and the industrial and service sectors are normally unable to absorb a large number of labourers under secure contracts. Therefore, the seasonal migratory pattern is common for members of this farm type.

Three sub-types of farmers were identified according to their access to water resources and off-farm income, both factors influential in their choices of farm production. Farmers belonging to sub-type A3, who have better access to water, have usually adopted integrated farming practice. Seasonal and more-permanent migration is found, but the migratory patterns do not significantly relate to their current access to water. A1 and A3 farmers usually migrate seasonally but migrant workers generate relatively low income. A2 farmers receive higher remittances but they often use it for home improvement and their children's education.

5.2.2. Farm type B: Medium-sized Rice-based, and Integrated Farming; More Market Oriented Farms

This farm type evolved from medium-sized farms studied in 1994 through the increased adoption of farm machinery along an evolving trajectory (Table 5.2). This type of farmer's main objective is to produce high quality KDML105 rice for sale and to increase land productivity through integrated farming. Unlike farm type A, their size is not a main constraint. Thus, it is possible for these farmers to consistently set aside enough area planted to glutinous rice to meet family needs, while adjusting the KDML105 area to cope with climatic risk. The key constraint here is labour shortage at peaks of labour demand periods of the RLR crop cycle. Type B farms are employing local labour during RLR transplanting and harvesting periods, as these two operations cannot be fully mechanized under local conditions. Their implementation by manual labour also ensures a better quality of the product, particularly at harvest. This is very important as high-quality paddy can help to compensate for the low yield achieved in this RLR agroecosystem. For example, the government- supported price for quality aromatic jasmine rice is 19,000 baht/ton for 2008 main harvest, compared with only 12,000 baht/ton, and 9,000 baht/ton for ordinary non-glutinous rice and glutinous rice respectively (Thai Rice Mills Association, 2008).

Their integrated farming activities are generally found near the house where it is easy to monitor them and collect products for family consumption. Because the farm area is relatively large (7.2 ha on average), the lowlands are planted to rice, while cassava and long fibre crops are produced in upland areas. But many farmers have replaced those other crops with cashew nut since 1996, and Para rubber plantations since 2000. However, cashew nut production had limited success because of low yields. Para rubber, on the other hand, seems more successful because of the support of state agencies, and its current high market price.

Table 5.2 Change among the three main types of farmer in Lam Dome Yai between 1994 and 2000- 2004.

Type		***A:** Very small rice-based and subsistence oriented farms*		***B:** Medium-sized rice-based and integrated farming, more market-oriented farms*		***C:** Large market-oriented farms with diversification out of rice or high remittances*	
Changes between 1994 and 200-2004		*Change*	*Consistent*	*Change*	*Consistent*	*Change*	*Consistent*
Family situation		• Smaller farm size • More rental of land	• Rice producing farm. • Self-subsistence farm • Cattle as saving asset	-	• Rice produced for both family consumption and sale of surplus	-	• Diversified farm productions • Rice produced for both family consumption and sale
Determinants of family choices	*As strategic constraints*	• Smaller farm size	• Low land per labour ratio • Lack of cash flow for investment • Poor access to water resources	• Larger farm size causing higher land per labour ratio	• Labour shortage	• Larger farm size causing higher land per labour ratio	• Labour shortage
	As strategic potentialities	• More water storage and use of agricultural machinery e.g. motorized water pump	• Extra labour for off-farm jobs	• More farm machinery used	• Good access to water resources	• More farming contracts • High remittances	• Diversify farm productions. • Good access to water resources
Strategy	*Choice of productions*	• Integrated farming introduced • More poultry and fish productions for family consumption	• Produce rice	• More livestock rearing	• Produce rice • Integrated farming	• Fish production • Perennial plantations (para-rubber)	• Produce rice • Integrated farming
	Choice of management	• Rent more land and agricultural machinery • Become major source of hired labour in village • More migrants working off-farm	• Use mainly family labour including returned migrants to produce rice.	• More use of chemical inputs and farm machinery. • More hired labour	-	• Invest more in international migration of family labour	• Use farm machinery and hired additional labour
	Choices concerning the production system	• Off-farm and on-farm employment to improve household income • Products from integrated farming for home consumption	• Glutinous rice for family consumption • Non-glutinous jasmine rice for sale	-	• Glutinous rice for family consumption • Non-glutinous jasmine rice for sale • Livestock rearing for sale • Products from integrated farming for home consumption	• Fish and fingerlings produced for sale • Products from perennial plantation for sale	• Glutinous rice for family consumption • Non-glutinous jasmine rice for sale • Products from integrated farming for home consumption

Livestock rearing is also an important source of income. Therefore, a significant herd of cattle and water buffaloes (10-20 heads) is usually raised. Water availability through the presence of individual farm ponds makes year- round production of fruits and vegetables through integrated farming possible. Furthermore, it is often used to water RLR nurseries at the beginning of the rice-growing season. To better match farming activities with the labour force available, sometimes farmers lease part of their land to relatives or type A neighbours.

Although off-farm employment can be an important additional source of income for some farmers, most of them are likely to keep all available family workers to manage their own farm activities. But some farmers have more-permanent migrants who do not return home to help their family members to grow rice. These migrants generally remit money back home so that their family can hire additional labour when needed. Even if indebtedness is a problem, these farms have some capability to invest in agricultural production through savings assets (livestock herd) on B2 farms and relatively high remittances in some cases (B1 sub-type).

5.2.3. Farm type C: Large Market Oriented Farms with Diversification out of Rice or High Remittances

These are the most well-off farms, having evolved from the extensive rice farming holdings studied in 1994 (Table 5.2). This farm type is characterized by relatively large holdings, averaging 8.6 ha. Their objective is to maximize labour productivity through diversification out of rice into Para rubber plantations, livestock rearing, and fish and fingerling productions. If the diversification out of rice is not used to increase labour productivity, more-permanent off-farm employment is an important strategy used to increase household income. Because farm workers belonging to this farm type have a generally high level of education, they have access to better paid employment opportunities e.g. working abroad and as government officers. Thus, their family members in the village usually receive regular remittances.

Two sub-types can be distinguished under this farm type. Both are large rice-based producers who try to rely on family labour and farm machinery rather than hired labour. But they differ in the strategies used to increase labour productivity. C1 farms use farm diversification out of rice; these households can keep all members busy on their own farm. In contrast, C2 holdings, which have a long experience in off-farm employment, often sell labour according to market demands, and thus receive high remittances. Rice is grown on a large area and farm diversification is less developed.

Of course, this farmer typology is an oversimplified presentation of the diversity of situations, and where all individual farmers cannot be represented in a model, but it does depict major differences among holdings. A limited sample of different farms from among the three core farm types can be used to represent the heterogeneity of the greater farming community. Figure 5.2 summarizes the functioning of these three main farm types to display the relationships between the families' objectives, opportunities/constraints and their respective selected strategies. The economic outcomes resulting from such relationships and choices are an important determining factor of migratory patterns. Once households in a particular village are classified, it is possible to typify the village by aggregating the characteristics of the households (Rindfuss, Jampaklay et al., 2004). Farmers belonging to the same type are likely to have similar decision-making processes regarding farming activities and migration practices. It is important that the processes are integrated into a model. Furthermore, this farmer typology is useful in the selection of potential participating farmers; the typology aims to ensure a broad representation and participation of the whole farming community in the Companion Modelling activities described below.

5.3. Importance of the Interaction between Land & Water Use and Labour Migration for Local Rural Development

Understanding land and water use in relation to labour migration in this RLR ecosystem is a very complex issue because of the numerous interacting components involved, such as the biophysical and socio-economic dynamics. Labour migration has emerged from agroecological constraints limiting farm productivity, shaped by natural endowment and its deterioration, in interaction with state policies, interventions and other socio-economic factors. As a consequence, the labour shortage occurring in the village is an outcome of migrations, leading to changes in farming practices affecting the use of land and water resources.

The scarcity of farm workers on some holdings has a negative impact on medium and large farms because of the higher labour costs, but a rather positive one on small holders as it provides an alternative source of income. In my case, a brief account of land and water use influenced by labour migration will illustrate the key human-environment interactions leading to complexity. Understanding these interactions by involving the concerned stakeholders is critical to discover acceptable and appropriate local rural development pathways.

5.3.1. Complexity as a Result of Interaction between Rainfed Lowland Rice Ecosystems and Socioeconomic Dynamics

According to Woodhill and Röling (1998), the complexity with which humans have had to deal with has escalated as forms of knowledge expand, and as social and environmental influences become global. Therefore, to understand a current complex phenomenon, it is necessary to look at human-environment interactions as a cause of complexity through social learning and knowledge exchange involving all concerned stakeholders.

The concept of reductionism has been used to explain natural phenomena based on deterministic, linear, equilibrium-based predictable interactions among objects and forces, and oriented towards sequential change. Model implementation under this physics-based concept represents only interactions between natural forces that have been proved to be accurate (Mann, 1991). However, this concept has limited explanatory power when dealing with non-linear, irreversible dynamics and evolution often found in biology, economics, or in social sciences. In this case, the key focus is on human behaviour in the system characterized by subjectivity, uncertainty, and self-organization resulting from interactions among heterogeneous components. To overcome these limitations, the concept of complex adaptive systems was introduced by scholars in the field of economics and social sciences. Complexity is related to the various manifestations of life, and the emergence of a complex system at a macro scale always involves interactions between micro-components in the system (Janssen, 2002; Nicolis and Prigogine, 1989).

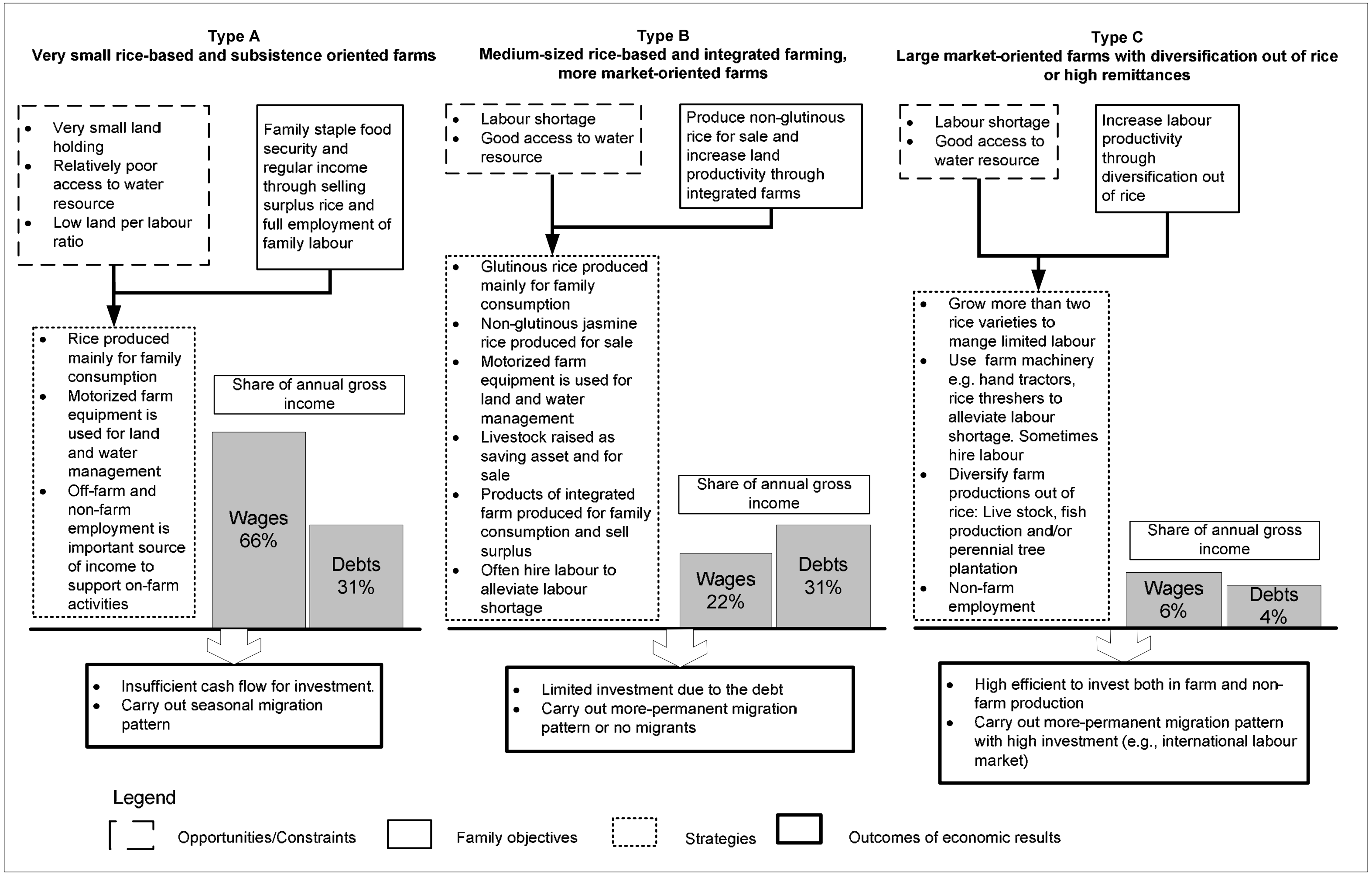


Figure 5.2 Diagrammatic representation of the functioning of the three main types of farming households in Ban Mak Mai village, Klang sub-district, Det Udom district, Ubon Ratchathani province (2007).

Four decades ago, the agroecosystem in the Lam Dome Yai watershed was not very complex due to fewer interacting components and actors aiming only at the exploitation of natural resources for self-subsistence. Today, this system is a very complex one as a result of more diverse actors involved at multiple levels and interacting with change within a larger system boundary. The next section will provide insight on interactions between land and water use, and labour migration in this study area through cause-effect relationships.

5.3.2. Causal Relationships between Land and Water Use and Labour Migration in the Study Area

In this study, labour migration is seen as an adaptive management strategy for resource-poor farmers to mitigate climatic risk and alleviate poverty. Migrating to seek relatively better paid employment and remitting money to the place of residence is theoretically a way to stabilize household income (Rattanawarang and Punpuing, 2003). In the context of Ban Mak Mai residents, farm workers are motivated to migrate as a result of poverty because of feeling poor (relatively) rather than because of absolute deprivation (Skeldon, 2002). Increasing household expenses through farm inputs, such as chemical fertilizer, pesticides, farm machinery, and the purchase of more consumer goods by the day in an increasingly commercialized Thai society drives local farmers to search for additional income.

Figure 5.3 depicts the causal relationships of labour migration by linking key factors at macro and meso-levels. According to neoclassical economic theory, macro factors like the low price of farm products, and rapid industrial growth are key pulling forces. Meanwhile, local residents feel relatively poor as a result of low residential satisfaction due to an unfavourable agroecosystem and unavailability of job opportunities. Interregional income inequality at the national level also pushes farm workers to migrate to seek better paid jobs.

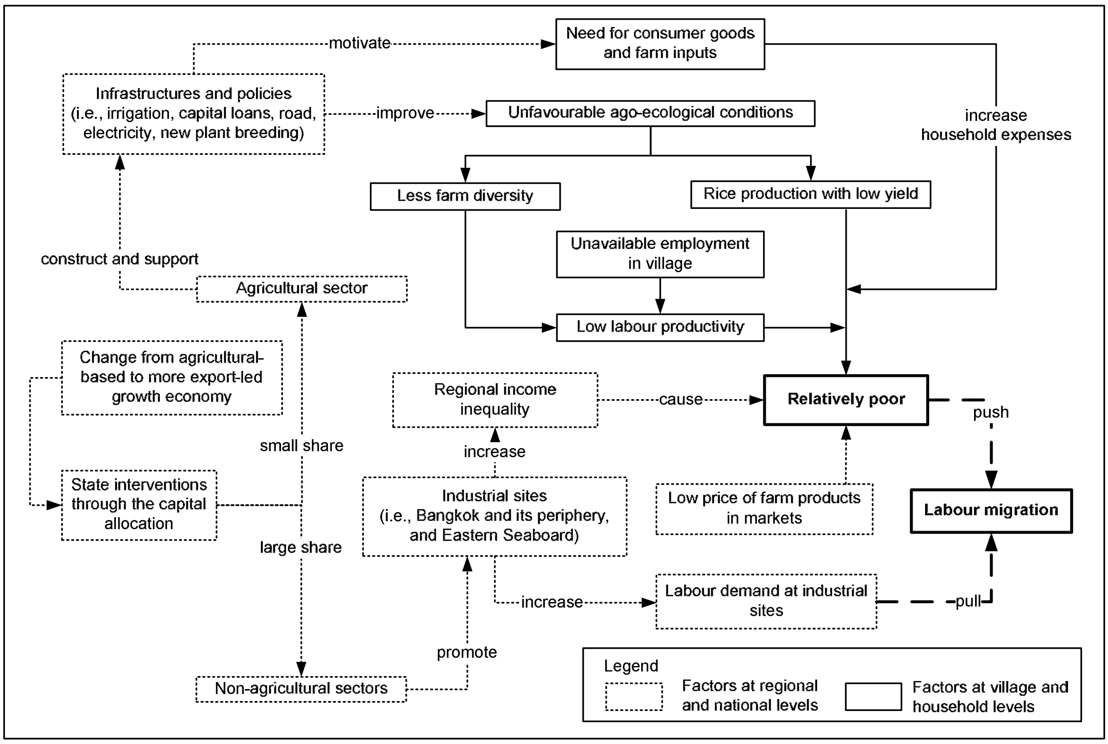


Figure 5.3 Causal relationships of labour migration reflected by macro and meso factors influencing farm production in northeast Thailand.

Figure 5.4 depicts the consequences of labour migration on a sending village like Ban Mak Mai. Labour shortage for farm production is an eminent problem at household and community levels once family workers decide to take off-farm employment outside of the village. Migration of family workers changes the pattern of allocation of work within a household (Shinawatra et al., 1996) and affects the ways that land and water are used. These macro- and meso- factors of land and water use related to labour migration provides a holistic view of the situation under study. However, this causal relationship inadequately represents the migration decision-making process at micro level. Integration of this holistic knowledge into the V-E model (see detail in chapter 3) provides a more comprehensive and integrative migration model that enables the implementation of individual migration decisions in my model.

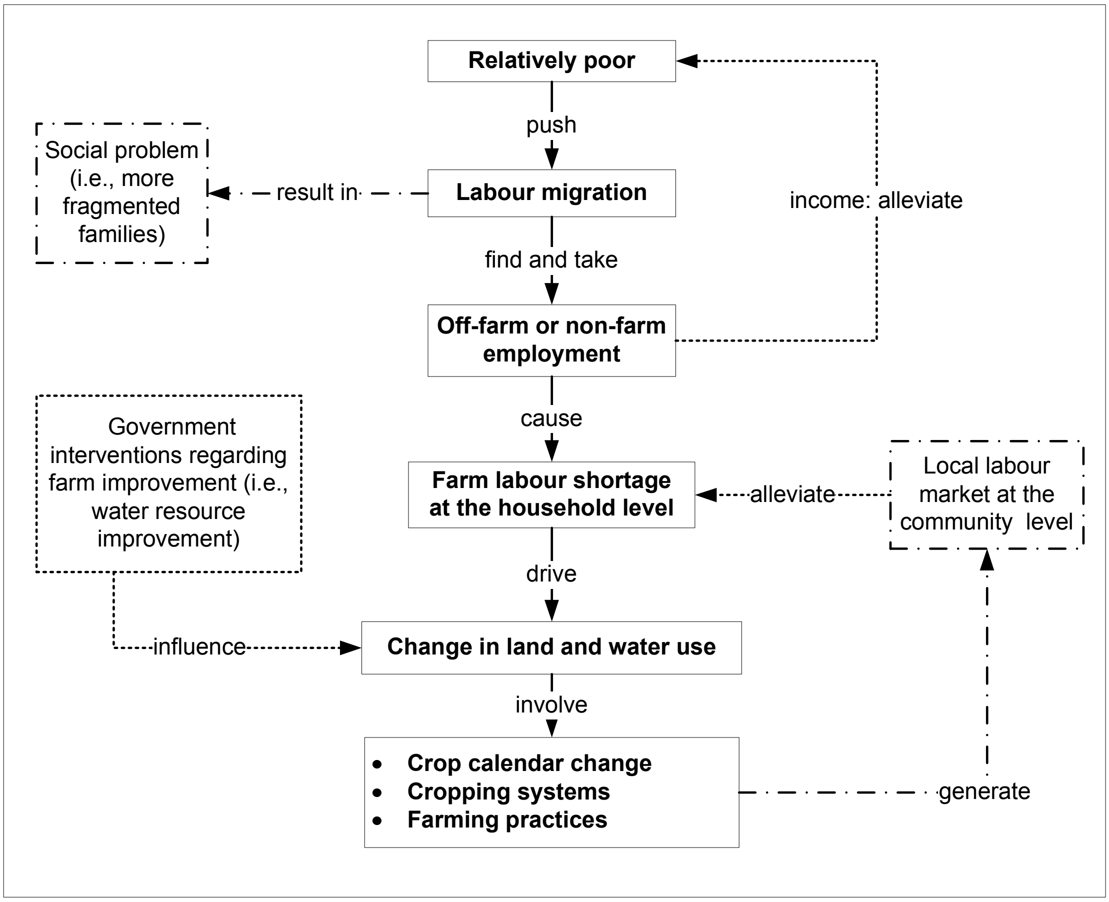


Figure 5.4 Impact of labour migration on change in land and water use at household and village levels in a sending community.

Regarding changes in cropping systems, medium to large farmers (types B and C) who usually grow dry season crops face serious labour shortage since many farmers migrate to cities during this period. They have to downsize the area planted to dry season crops or even stop producing them (Paris, 2003). For changes in farming practices, some local rice farmers adopt direct seeding technique to mitigate the labour shortage problem at RLR crop establishment, while well-off farmers often invest in farm machinery to replace human labour (see chapter 3 for more details about changes in farming practices in relation to labour migration). Because of advanced market integration and competitive labour recruitment, mutual help among relatives does not exist anymore. Instead, a local market for hired labour has emerged in response to the increased demand for farm workers to help alleviate labour shortage at the village level. Moreover, pools of illegal foreign workers from Laos and Cambodia are also becoming available for hire at lower cost at RLR harvest.

5.3.3. Need for Comprehensive Knowledge about Interactions between Land & Water Use and Labour Migration prior to Implementation of Major State Investments in Water Resources

Most of Thailand's agricultural development projects have been implemented by focusing on improving agroecological conditions, while usually ignoring the socioeconomic dimensions. In the northeast region, the improvement of water availability has been the focus of many past governments. Regional irrigation projects have aimed at improving local farmers' livelihoods by extending their ability to produce farm products for sale, particularly in the dry season. However, the success of state attempts to support all-year round farm production is limited as seen by the consistent flow of labour migrations from the northeast to Bangkok and other urban areas.

Moreover, the establishment of local administrative organizations (TAO) to manage local resources according to the national policy of decentralization makes the participation of locals in any development projects at the community level mandatory (Charoensutipun, 2001). Recently, without a clear understanding of such interactions among key components of the system, and a lack of involvement of locals, the Royal Thai Government has been preparing an extensive water grid system to ensure that sufficient volumes of water feed huge areas of the country, in particular the dry and impoverished northeast region (Molle and Koma, 2005). A 500,000 million baht (one billion euro) mega infrastructure project to divert water from the Mekong river through a "hydro-shield tunnel" is often cited (Bangkok Business News, 2008; Matichon, 2008).

Such top-down development approaches cannot handle such complex interactions. An in-depth understanding of these key interactions acquired through truly participatory approaches is definitely required to ensure the design of useful, acceptable and practical development plans prior to their implementation. Initially, this understanding is also necessary to improve my preliminary knowledge before model implementation. The results from subsequent simulations can answer questions related to possible future scenarios. The exploration of scenarios with local farmers is a promising way forward for researchers, decision-makers, and policy makers to begin future interventions in a collaborative and more bottom-up fashion.

PART 2 COMPANION MODELLING (COMMOD) TO UNDERSTAND THE INTERACTION BETWEEN LAND & WATER USE AND LABOUR MIGRATION

CHAPTER 6
COLLABORATIVE MODELLING APPROACHES FOR RENEWABLE RESOURCE MANAGEMENT

Collaborative or participatory approaches emerged as a response to lengthy and top-down planning processes in rural development projects and to the failure of the transfer-of-technology model which had been predominant from 1960 to the early 1980s (Neef, 2005). Such technological transfers are likely to fail in highly heterogeneous and marginal areas when top-down developments are implemented regardless of the involvement of concerned stakeholders (Ashby and Sperling, 1995). However, when stakeholders are involved, inviting them to participate is often not genuine: they are merely sought to increase the legitimacy of developments projects (Bishop and Davis, 2002).

Genuine implementation of participatory processes requires the use of interactive techniques. Organizing workshops based on collective model building, scenario development and exploration represents one of the most promising techniques to set up a communication platform generating multi-directional flows of information between stakeholders (Stringer, Dougill et al., 2006)

In this chapter, collaborative modelling refers to the process of designing and/or using models collectively, as distinguished by Renger, Kolfschoten et al (2008). Several similar terms are used to refer to the same general principle: group model building (Vennix, 1996), mediated modelling (Van den Belt, 2004), cooperative modelling (Cockerill, Passell et al., 2006), and participatory modelling (Hare, Letcher et al., 2003). This chapter begins with general considerations about models and the modelling process. The collaborative modelling approach is then introduced and to illustrate its diversity, a comparative analysis of six collaborative modelling case studies is subsequently presented in this chapter.

6.1. Diversity of Models, Sequentiality of the Modelling Process

6.1.1. Characteristics of Models

A model is a simplified representation of an actual system, a synthesis of what we know about the system with references to the problem at stake (Banks, 1998; Jorgensen and Bendoricchio, 2001). There is a huge diversity in the types of models and many criteria can be considered to propose a typology of models. The most commonly referred criteria are briefly reviewed below.

A physical model is a real manipulable artefact such as a scale model of an aeroplane used for aerodynamic testing in a wind tunnel (Jorgensen et al., 2001). In contrast, models without a physical existence are called “abstract” models. This category can itself be classified into three subcategories: conceptual, mathematical and computational models. Conceptual models are simple drawings: diagrams. Mathematical models make use of equations to depict the reference system. Computational models are designed by using programming languages or specific software.

Time is another dimension to characterize models (Alan and Banks, 1998). In static models, the changes in variables defining the system are not dependent on time, which is the case for dynamic models. Dynamic models can be further classified into discrete-change and continuous-change models. The spatial representation is also used to classify types of model. Spatially-explicit models, frequently used to tackle RRM issues, provide a representation of space. However, many disciplines use the term ‘spatially explicit’, but in different ways. Four tests are proposed by Parker (2001) to determine whether a model is ‘really’ spatially explicit.

6.1.2. Objectives for the Implementation of a Model

The objectives for the design and use of a model are often specific to each case study. Therefore, like model characteristics, they are also very diverse. Yet publications presenting models do not always provide clear indications about the objective related to the models. This is an issue, as the objective drives the design of a model and has to serve as the main justification for modelling choices. Four main objectives often cited are: (i) to understand the system or problem in a virtual laboratory (as explanatory devices); (ii) to determine critical elements, components, and issues and to estimate performance measures (as an analysis tool); (iii) to represent system operation and a means of communicating science and the results of science (as a communication vehicle), and (iv) to predict the consequences of proposed scenarios. (Carley, 1999; Epstein, 2008; Jorgensen et al., 2001; Wainwright and Mulligan, 2004).

Nonetheless, to investigate the complexity of human-environment interactions at work in socio-ecosystems, abstract simulation models are usually implemented. The modelling objectives are then to gain better understanding about the system under study, to promote communication, and to support decision-making.

6.1.3. The Sequentiality of the Modelling process

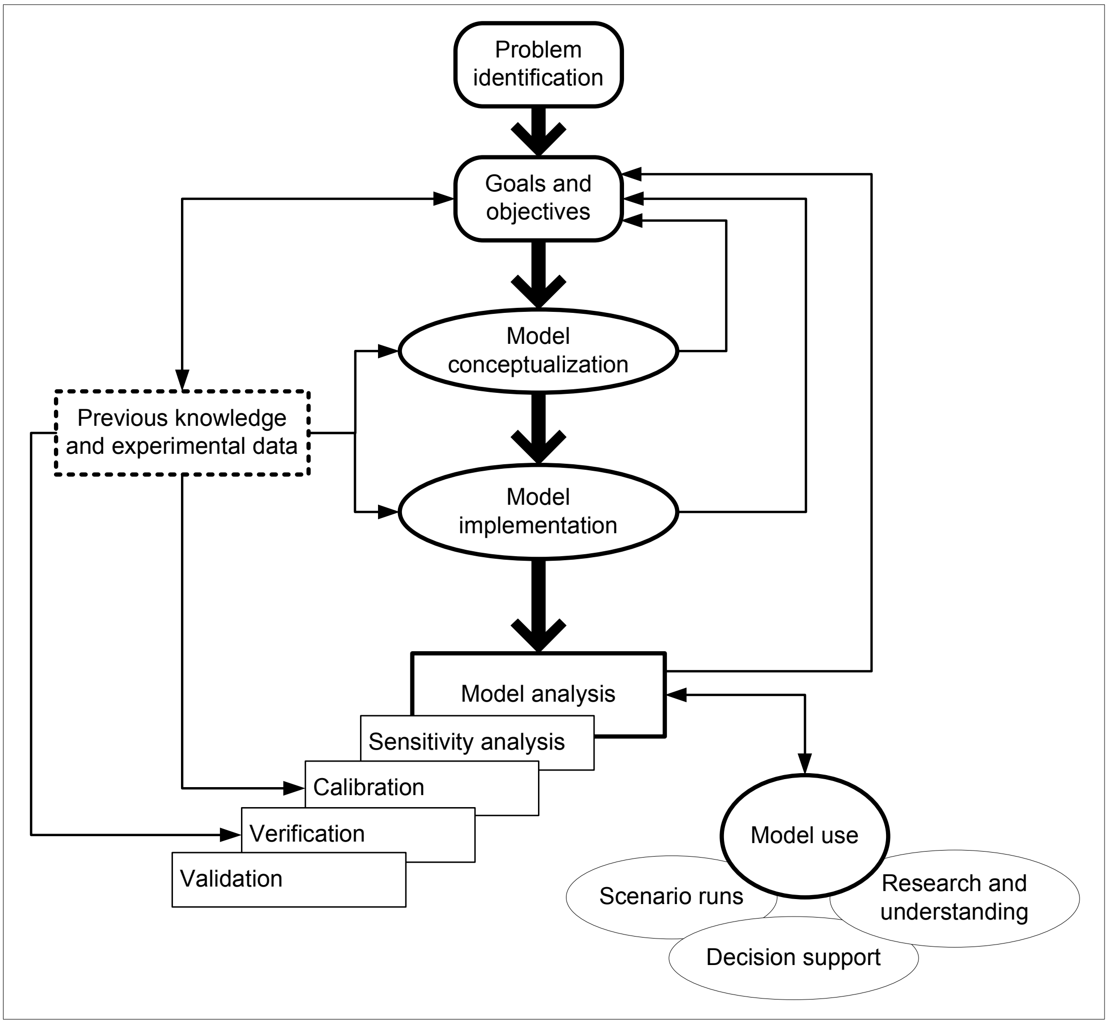
Figure 6.1 shows the key stages of the modelling process as proposed by Voinov and Bouman (2004). Different modelling stages have been proposed by several authors (Banks, 1998; Jakeman, Letcher et al., 2006; Komklom and Puckdeewattanakul, 2005). Unlike model characteristics and objectives, descriptions of the modelling process share strong similarities. The various terms used to identify the modelling stages can be grouped into *two* main phases: model design and model use. It is also commonly stressed that the modelling process is unlikely to flow linearly but rather comes and goes iteratively between stages.

6.2. Collaborative Modelling Approaches

There are some stages in the design and/or use of models that involve several persons. The term ‘collaborative’, or ‘participatory’, modelling refers to such group model building situations where model designers and/or users are actively involved (Eden et al., 1996).

6.2.1. Collaborative Modelling Background

Collaborative modelling approaches stem from system dynamics, and usually refer to integrated ecological modelling. The idea is that a system’s point of view is helpful to ‘lift’ observers to the system’s level and to create a holistic view. Several methods have been developed to support such an idea, ranging from problem structuring and the system’s conceptualization (e.g. cognitive mapping) to the construction of computer models simulating the behaviours of stakeholders interacting within a complex socio-ecosystem.



Source: adapted from Voinov and Bouman, 2004.

Figure 6.1 An example of the sequentiality of the modelling process.

In ecology, hard and soft systems are often referred to (Röling and Wagmaker, 1998). Hard systems are treated as if the systems really exist. The systems' boundaries and goals are assumed to be given. Analysis and problem solving focus on goal seeking and the best technical means to reach a goal. The crucial assumption is that system goals are not given but contested, and that system boundaries are negotiated. The soft systems methodology emphasizes a group of actors who are faced with a shared problem to engage in a collective learning process. A combination of both systems methodologies (soft and hard sciences) and participatory action research can theoretically facilitate the integration of various disciplines and different types of knowledge. Such a combination is consistent with the definition of soft systems methodology, and is referred to as collaborative modelling (Purnomo, Yasmi et al., 2003).

6.2.1.1. Diversity in Collaborative Group Composition

The types of disciplines and number of collaborators involved in the modelling process can determine the base of knowledge integrated into the model. Frequently, modelling has primarily been used by natural scientists as a means of capturing and predicting aspects of complex systems, usually within monodisciplinary boundaries (e.g. crop models, hydrological models). These kinds of “expert models” are inadequate to understand non-linear, complex and dynamic systems such as in the field of economics where several components of human-environment interactions are involved (Prell, Huback et al., 2007). Thus, economists have adopted modelling in different ways to integrate the product of several disciplines into an economic model. However, these multidisciplinary models are usually implemented and used within the scientific arena. This kind of modelling approach is based on optimization and ‘factual knowledge’ that is insufficient for multi-level and multi-actor involvement, in particular rural development (Prell et al., 2007). The involvement of lay stakeholders throughout the model development process is proposed to avoid relying exclusively on knowledge derived from policy-makers and scientists (Purnomo et al., 2003). Therefore, the engagement of non-scientific stakeholders is needed if investigation of a RRM issue is targeted.

Participation of non-scientists in the production and use of scientific knowledge was introduced by social scientists who believe that science is socially constructed and should not be restricted solely to the scientific arena. Research on participation in science pay more attention to gaining support for decisions and enriching assessments with lay-knowledge and opinions (van Asselt, Mellors et al., 2001). Involving non-scientists in the research process is increasingly important in the analysis of complex issues. Such issues concern a tangled web of related problems (multi-problem), lie across or at the intersection of many disciplines (multi-disciplinary), and the underlying processes interact on various spatial and temporal scales (multi-scale) involving different stakeholders (multi-actors) (van Asselt and Rijkens-Klomp, 2002). However, indigenous knowledge alone is not sufficient

(Ostrom, Schroeder et al., 1993). Thus, integrating knowledge from different sources through collaborative processes can be a promising way for all relevant stakeholders to gain better understanding of the current situation of the system under study.

6.2.1.2. Collaborative Model: the Integration between Local and Scientific Knowledge

Knowledge integration that combines local and scientific knowledge is a challenging issue in scientific research (Neef, 2005). Local knowledge is primarily concerned with sustaining people's livelihoods in harmony with nature. It is closed, non-systematic and bound to subjectivity, common sense or superstition. In contrast, science is open, systematic and objective, rigorous and analytical.

Because local knowledge is deeply embedded in the social, cultural and moral context, it is important to better understand this informative base of a society. Such information is needed to facilitate communication and decision-making resulting in the creation of an environment. This is conducive to collaborative processes that bridge the divide between local and scientific knowledge. Thus, in a collaborative modelling process, stakeholders play a proactive, central role in the design team, working together with modellers that can result in more practical designs and acceptable development (Schuler and Namioka, 1993). Through the collaborative and communicative platform, the knowledge-sharing activity is enhanced leading to shared representation developed among heterogeneous stakeholders (Ashby, 2003; Narayan, 1996; Pahl-Wostl, 2006; Selener, 1997). The collaborative modelling process also supports capacity building (Fitzpatrick and Sinclair, 2003), helps to resolve conflicts and build consensus (Walkerden, 2006), and creates networking opportunity (Roux, Rogers et al., 2006).

6.2.2. Collaborative Modelling Phases

Collaborative modelling process is a continuous spiral of collective decision cycles generally consisting of five main phases: problem identification and structuring, model conceptualization, model implementation and validation, scenario exploration, and monitoring and evaluation of the model used (Daniell and Ferrand, 2006). The degree of stakeholder involvement, in the collaborative modelling process, is varied. They can engage exclusively during the model design phase or simply be the end users of the model; the model can also be co-designed with, and used by the stakeholders.

6.2.2.1. Model Design Phase

Problem identification and formulation

This phase underlies the theory to elicit the individual perceptions to determine the nature of the situation where the problem is found, what elements are important to the problem, and how participants believe these elements to be related to one another over a variety of scales (Daniell et al., 2006). The aim is to create a shared understanding about the identity and extent of the problematic issues. It also allows a group of people to become acquainted with each other along with the development of problem structuring (Andersen and Richardson, 1997; Winz and Brierley, 2007).

In this phase, the involvement of a broad representation of stakeholder groups affected by the problem is essential. While the problem is collectively structured, the objectives to be achieved or situations to be avoided are also often determined. Once objectives are elucidated, potential processes, strategies or plans can be designed. The preliminary findings at this phase are useful for formalizing an initial conceptual model.

Model conceptualization

The model conceptualization is an analytical task that abstracts the system into a model described by elements of the system, their characteristics, and their interactions (Musselman, 1998). The representation of the users' perceptions and conceptions in relation to the system where the users reside is reflected in the conceptual model (David, 2002). Maintaining stakeholder involvement and using information provided by participants during this stage can create trust in the modeller and the model-building process (Ford and Sterman, 1998). A conceptual model can be presented in various kinds of visualization ranging from simple and organized writing or diagrammatic flowcharts to computer-based applications. It can be used as a tool to facilitate effective and efficient communication between participants regarding a model's structure, components and operations (van Asselt et al., 2001). Once the initial conceptual model is formalized to sufficiently represent the system under study, it is developed to become an artefact aiming to further analyze the effect of potential actions may occur under defined problematic situations.

Model implementation and validation

This modelling stage captures the conceptual model using the constructs of a simulation language or system. Translation of the conceptual model into a programmed model constitutes the process of programming to build an executable simulation model. Additional information beyond the initial thinking is usually obtained during this model co-constructing activity. It includes re-examining the hypotheses used in the model, and refining the work of model development through verification and validation procedures. Three significant steps in the modelling procedure need to be defined in this section. They are calibration, verification and validation (Jorgensen et al., 2001). Calibration is an attempt to find the best accordance between computed and observed data by variation of some selected parameters (Hansen and Heckman, 1996). If not, the model is adjusted by modifying the values of certain parameters. Verification is a determinant of whether the computer implementation of the conceptual model is correct. It is a test of the internal logic of the model, and a subjective assessment of the behaviour of the model.

Once a model is operational after verification testing, the model needs to be checked for its validity and whether or not it is a good model of what it is supposed to represent. Validation is a determinant of whether the conceptual model can be substituted for the real system for the purpose of experimentation (Balci, 1998). An objective is to test how well the model outputs fit the data. Since the model is co-constructed with field collaborators, the model validation is often carried out in parallel with model implementation. Involving stakeholders can ensure that the content of the model is believable, its outcomes plausible, and that it sufficiently represents the problem being examined (Daniell et al., 2006). Successful projects depend on valid models, sound statistical analyses, and cogent reasoning (Musselman, 1998). It is important that model validity is accepted by stakeholders. Once the programmed model is completed and valid, it is ready to be used for running virtual experiments. The process of experimenting with the simulations is to evaluate system behaviour, to analyze model sensitivity, to determine functional relations, and to train people involved in the modelling process (Balci, 1998).

6.2.2.2. Model Use Phase

This phase focuses on producing scenarios and management options by using the model. The scenarios to be analyzed should be collectively identified and explored by stakeholders. Possible solutions for desirable solutions are collectively analyzed through the outputs of simulations. However, no model can replace individual thought. Thus, the purpose of using models at this phase of the collaborative modelling process is to support the collective decision-making process, not to supplant it (Daniell et al., 2006). Neubert (2000) proposed two efforts that should be taken into account once carrying out scenario exploration. First, the discovery-oriented effort is to produce new knowledge about organizational or institutional innovation processes. Second, the literacy-oriented effort is to build individuals' and communities' capacities to handle their problems themselves. In reality, both discovery- and literacy-oriented efforts are often interlinked.

After exploring interesting scenarios, the synthesis of preferred actions drawn from desirable scenarios can be collectively assessed for the purposes of making a final decision and a collective agreement to implement an action plan. As stakeholders actively involved in the model design phase, their acceptance of and commitment to a model's outcomes is high. Other positive outcomes can be increased independence, self-awareness, and empowerment of stakeholders to address local problems independently.

6.2.2.3. Monitoring and Evaluation

The monitoring and evaluation activity plays an important role in assessing the success of the collaborative modelling process. This activity is proposed to ensure that tasks are carried out according to the action plan. Any problem encountered can be treated on an ongoing basis through adaptive management. As an intervention measure, if the evaluation is carried out by the participants, they will be required to think about what is occurring in the process which can then potentially change their behaviour and have further impacts on the process and its outcomes (Daniell et al., 2006). As an aid to the overall utility, outcomes and perceptions of the process can be used to determine how such a process can be improved.

6.2.3. Methods and Modelling Tools

Although the participants collaboratively working with modellers is important, methods and modelling tools used are also a determining factor in successful collaborative modelling. Group discussion is often a primary method in collaborative modelling. Other participatory methods (individual interviews, focus groups, etc.) can be used in the collaborative modelling process as well. Tools can be simple drawings or complicated computer simulations, or combination of both.

Methods and tools used in collaborative modelling aim to examine the system under study qualitatively and quantitatively. For qualitative methods, the cognitive mapping using software packages such as Decision Explorer and DANA, and problem structuring methods such as the Soft Systems Methodology and Strategic Choice Approach are usually acknowledged. There are many methods dealing with quantitative investigation raging from static representation for instance, spatial mapping through public participation GIS, to more dynamic models such as System Dynamics (STELLA and VENSIM), Multi-Agent Systems (CORMAS and REPAST), Multi-Criteria Analysis (PROMETHEE methods), and Probability and statistical methods, such as Bayesian Networks (Daniell et al., 2006). Six case studies with different methods and tools used are analyzed and compared in the next section.

6.3. Comparison of Six Case Studies in the Field of Collaborative Modelling for RRM

This section presents the production collaborative modelling in six case studies under the RRM study domain. In the case of the qualitative method, causal loop diagrams were a main tool for a collaborative modelling conducted by Purnomo et al. (2003). These diagrams were used to establish relationships between key components, integrate different stakeholder perspectives, and agree on performance indicators of forest management in Indonesia. A cognitive map integrated with critical system thinking was used to develop a “facilitative device” in lower Mekong delta, Vietnam (Nico Hjortsø, 2004).

For the system dynamics, several studies have used system dynamics models to facilitate group discussion, particularly for data acquisition and decision support purposes (Gilbert, Maltby et al., 2002; Mayer and De Jong, 2004; Voinov and Gaddis, 2008; Winz et al., 2007). An increasing number of studies have adopted gaming, and computer simulation models, in particular the ABM, to facilitate social learning aimed at understanding current situations that has the potential to lead to better management decisions through a collaborative modelling process (Barreteau and Bousquet, 2000; Becu, Perez et al., 2003; d'Aquino, Le Page et al., 2003; Liu, Takeuchi et al., 2007). For the GIS-based collaborative modelling, Gonzalez (2002), Ranbalsi (2005), and McKinnon (2005) used GIS technology to integrate indigenous knowledge into a scientific one with a group of local stakeholders and GIS experts through participatory GIS map-generated development. These methods help to increase the participation of domain experts in the modelling process to support creative, interdisciplinary, collaborative exploration, and promote better designs. They also enable domain experts to validate that their domain is represented correctly in a conceptual model (Sullivan, 2004). Six case studies with different methods used in collaborative modelling are presented.

6.3.1. Cognitive Mapping and Soft Systems Methodology

The study site of the Damdoi Forest Enterprise (DFE) case was located in the lower part of the Mekong delta, Vietnam. Nico Hjortsø et al. (2005) studied the implementation of a buffer zone to protect against large-scale mangrove deforestation caused by the expansion of shrimp production and conflict between shrimp farmers and DFE over the establishment of a protected area. In this case study, the objective was to find a method to prepare facilitators of participatory inquiry and decision-making processes. This preparation and device produced was proposed to help facilitators obtain an in-depth understanding of the situation before conducting participatory activities. Eventually, the research team aimed to draw a buffer zone without critical conflicts with stakeholders. The Rapid Stakeholders and Conflict Assessment (RSCA) methodology, which integrates 4 methods— stakeholder analysis, conflict assessment, problem structuring, and critical system thinking—was used.

The soft systems methodology was applied to structure the problem with participation of concerned stakeholders. The Cognitive mapping (CM) method (Axelrod, 1976; Mendoza and Prabhu, 2006a) was used to capture parts of the personal construct system by modelling the perceptions of each group member in a CM developed during interviews to represent the network of concepts (notes) used to form chains of argumentation. All CMs were produced by using the software package "Decision Explorer". A facilitator analyzed these maps to indentify clusters of related concepts and merged them into a "facilitative device" that was used in problem identification and negotiation.

In this case study, CMs were useful for capturing stakeholder perceptions, their sense of dependency on the natural resource system and their interactions with other stakeholder groups, including existing and potential conflicts. However, without a temporal dimension, CMs made it difficult for participants to explore their interesting scenarios. Besides, without the spatial dimension evolving through time, participants had difficulty pinpointing where the impact was worse that urgently needed to be look after.

6.3.2. System Dynamics

Tidwell et al. (2004) applied system dynamics[5] (SD) to plan community-based water management in the Middle Rio Grade, north-central New Mexico. The problem was the imbalance between water supply and demand in this semi-arid region, and lack of stakeholder involvement in making development plans. The objective was to create a water resources model for community-based planning. This SD model was proposed to enable participants to quantitatively explore alternative water management strategies, educate them on the complexity of the regional water system, and engage them in the decision process.

[5] **System Dynamics (SD)** is a concept based on systems thinking where dynamic interaction between the elements of the system is considered to study the behaviour of the system as a whole. As the name suggests the behaviour of the system is monitored over time and is thus dynamic. The concept of SD was introduced by Forester (1961). The main idea of system dynamics modelling is to understand the behaviour of the system by the use of simple mathematical structures. SD concepts can help: (i) describe the system; (ii) understand the system; (iii) develop quantitative and qualitative models; (iv) identify how information feedback governs the behaviour of the system and finally, (v) develop control polices for better management of the system.

Causal loop diagrams were used to represent key elements influencing water supply and demand. The SD model was produced using Studio Expert 2001 and 2003. The model represents dynamics water budget as a result of interactions between surface and ground water stored in the basin varying annually in response to changes in the associated inflows and outflows. The model development process benefited from interactions with a community outside of the modelling team. The scientific knowledge was derived from water professionals and scientists. Public feedback from water forums, where various schools and universities, civic and professional groups participated, was integrated into the SD model. In this case study, SD provided a framework to integrate the disparate physical and social systems important to water resource management. The SD model was able to be used for interactive public engagement.

6.3.3. Multi-Agent Systems

The Multi-Agent Systems[6] (MAS) played a key role in "the participatory computer simulation to support collective decision-making" conducted by Becu et al. (2007) in Mae Sa watershed, Chiang Mai, northern Thailand. The problem was conflicts regarding water use between upstream and down stream villages as a result of water scarcity. The objective was to test the assumption that stakeholders can be confronted directly with an abstract computer model of human-ecosystem interaction. The research team also intended to use this abstract model as an explorative and decision-support tool to facilitate the negotiation over natural resources between stakeholders with conflicting interests.

The research framework of this case was one from the collaborative modelling family, the Companion Modelling (ComMod) approach (Barreteau, 2003b). An ABM

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[6] **Multi-Agent Systems (MAS)** originally came from the field of artificial intelligence (AI). At first, it was called distributed artificial intelligence (DAI). The objective was to reproduce the knowledge and reasoning of several heterogeneous entities called 'agent' that need to coordinate to solve planning problem. The coordination of actions or the construction of systems represents the consequences of interactions between relatively independents and autonomous agents operating within communities in accordance with what are sometimes complex modes of operation, conflict and competition in order to survive and perpetuate themselves. Organized structures emerge from these interactions, which in turn restrict and modify the behaviours of the agents. The characteristic of emphasizing interactions and, more precisely, of analyzing the interaction systems, which exist between agents is what distinguishes MAS from the more classical approaches, in that preference is given to emergence, and action and interaction are considered as the motor elements in the structuring of a system taken as a whole.

was built on the CORMAS platform by the modeller. This ABM was used as a tool to facilitate communication among stakeholders. Three successive rounds of participatory simulation workshops were organized to allow stakeholders to validate the model, and to engage stakeholders in the negotiation process about water allocation.

Simulation of water shortages stimulated knowledge acquisition. For instance, stakeholders found that the expansion of sweet pepper cultivation in the downstream village would solve the problem of water shortage in the village while a shift to gerbera in the upstream village would increase water shortages for both villages. However, due to the complexity of this ABM, it was difficult for stakeholders to familiarize, and to create a sense of co-ownership.

6.3.4. Multi-Criteria Analysis

Multi-Criteria Analysis[7] (MCA) was combined with participatory modelling to increase participation of local communities in forest management and make them realize the benefits from a forest through a resource-sharing program in the Mafungautsi Forest, Gokwe District of the Midlands, Zimbabwe (Mendoza and Martins, 2006b). The conflict of interests between state agencies trying to protect the forest and local communities exploiting the forest was a problematic issue. The research team attempted to carry out a group model building to develop a combined

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[7] **Multi-Criteria Analysis (MCA)** is a general approach dealing with problems that involve multiple dimensions or criteria. MCA's ability to incorporate multiple views from different stakeholders makes it an excellent tool for participatory planning and decision-making. MCA's ability to deal with mixed data add some rigor to what otherwise would be a highly subjective and qualitative planning and decision-making process. In a formal model, the decision-making problem can be described as:

Optimize $Z = f(\chi_1, \chi_2, \ldots, \chi_n)$ where $f(\chi_1, \chi_2, \ldots, \chi_n)$ is the objective function.

Formally, MCA is an extension of the problem described above, accommodating multiple objectives or criteria. That is, the problem can be described as follows:

Optimize $Z_1 = f_1 (\chi_1, \chi_2, \ldots, \chi_n)$
Optimize $Z_2 = f_2 (\chi_1, \chi_2, \ldots, \chi_n)$
Optimize $Z_k = f_k (\chi_1, \chi_2, \ldots, \chi_n)$ where $Z_1, Z_2, \ldots, Z_k$ are the different criteria.

Each criterion has varying degrees of importance. Each criterion must be measured, and their relative effects individually evaluated. MCA also provides the structured process, and the means to measure the cumulative impacts of all criteria. That is, MCA offers a systematic (organized and structured) and systemic (embracing individual and collective effects) procedure to measure and reflect not just individual effects, but also the cumulative impacts of all criteria.

MCA and SD model with all concerned stakeholders. Their assumption was that MCA can fill a gap in participatory modelling by offering the structuring and analytical capability to the open and collaborative nature of participatory modelling. As a result, the acceptable resource management alternatives among all concerned stakeholders can be obtained.

The participatory modelling process at the initial stage was carried out by using CMs in the Co-View software to produce a strategic planning 'SWOT' (Strengths, Weaknesses, Opportunities, and Threats including Indicators). Then, a SD model (stock and flow) was developed based on elements in the SWOT obtained from the CMs. The MCA and its projected values based on the impact of the action plan were produced by core participants (governmental officers and researchers), and applied to SWOT elements structured in the SD model.

Core participants grasped the potential of the simple model as an analytical tool that could help them in planning and in the decisions they have to make, often based only on intuition and past experiences. In the end, the participants were more confident in their ability to use the model in generating insights, especially with respect to impact assessments. However, a short-coming was the composition of the core group that may have minimized the possibility of divergent opinions, and increased the 'black box effect' on non-participating stakeholders leading to low potential for compromise. This was because none of the participants from local communities in the modelling process was indicated while the projected values were decided for MCA.

6.3.5. Probability and Statistical Method

In Sri Lanka, Cain et al. (2003) conducted a study to test a tool called a Bayesian Networks[8] (BNs) to see if it could be accessible to non-specialists and able to provide generic, flexible framework for the construction of a decision support system (DSS). The objective was to provide agricultural policy makers with a DSS so that they could

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[8] **Bayesian networks (BNs)** were originally developed as a formal means of choosing optimal decision strategies under uncertainty. Bayesian Networks are composed of three elements (i) a set of nodes representing system variables, (ii) a set of links representing causal relationships between nodes, and (iii) a set of probabilities (one of each node) specifying the belief that a node will be in a particular state given the sates of those nodes which affect it directly (its parents). These are called conditional probability tables (CPTs) and can be used to express how the relationships between the nodes operate.

identify problems and assess feasible and practical farm management solutions for farmers working in the Deduru Oya river basin.

In this case study, BNs are assumed to be more accessible for non-specialists to analyze a complex system. This is because the conceptual model to produce BNs is presented in diagrams of cause-effect relationships for group discussion. In addition, BNs embedded with Bayesian probability theory (Jaynes and Bretthorst, 2003) allow subjective data elicited from stakeholders to be used together with more objective data. Therefore, stakeholders can construct BNs to represent their different perspectives, and facilitate discussion of contentious issues so that conclusions can be reached and solutions are acceptable to all parties.

Two participatory workshops with different types of participants, policy makers and farmers, were organized. Participants from the government were formed into 4 groups. Each was guided by a set of instructions and facilitated independently. The participants managed to construct BNs by themselves. Another workshop with participating farmers was organized into two sub-workshops held in different places. Instead of letting the participating farmers construct BNs by themselves, semi-structured discussion was used to elicit the information necessary for the facilitators to construct a BN flow diagram. Questions similar to those used with governmental participants were asked. Two BN flow diagrams, one produced during the government workshop and another one interpreted by facilitators in the farmer workshop, were compared. It was clear that none of the groups were immediately comfortable with expressing their logic diagrammatically. But none of them had difficulties in capturing their ideas in terms of variables (nodes) and giving quantitative states (values) to those variables.

A pitfall found in this experiment was the subjective assessments made by individual groups and simple specification of state in BNs that could contribute to misleading results.

6.3.6. Spatial Mapping

In 2002, Gonzalez carried out a joint learning GIS with multi-actors living and working in steep mountainous area in Ifugao province, The Philippines. This unique landscape with handcrafted paddy terraces (UNESCO World Heritage) is facing a decline in traditional workgroups to conserve the area as a result of labour migration, and unsuccessful development paths proposed by state authorities. The research objective was to integrate spatial analysis capability and people's knowledge of their own space to understand the current problematic issues, thus leading to group discussion about feasible and practical development.

The primary medium of this participatory design was conversation. Aerial-photographs (1951 and 1980) and SPOT image (20 m solution) were used for the participatory image interpretation. GIS-generated maps using ILWIS GIS software were operated with stakeholders. Shared GIS-insights with the stakeholders were developed and evolved into local learning.

The most important outcome of this study was the successful communication among stakeholders about the fragile space in which they live. This was necessary in striving for the collective management of a common space. This study demonstrated that a participatory approach in designing a GIS could provide tools to facilitate thinking, negotiation, active social construction of natural resources, and collective decision-making (joint learning, social learning or collaborative learning). However, the limitation of this method was the lack of a dynamic dimension. Since maps represented only a 'snapshot' of the dynamic process, they could not be used to analyze the changes in short discrete time step. Another short-coming was the expensive software and hardware including materials such as satellite images.

6.3.7. Analysis of Six Case Collaborative Modelling Studies

This section presents the production of an analysis of six collaborative modelling processes in RRM. These case studies were analyzed following a proposed integrative methodological framework developed by the members of the "CGIAR Challenge Program on Water and Food (CPWF) PN 25: Companion modelling for resilient water management[9]" project in 2008. This framework is based on the experiences of the CPWF-PN25 team who use a collaborative modelling, the so-called Companion Modelling (ComMod) approach to understand individual and collective decision-making processes and practices (Barreteau, 2003b; Bousquet, Barreteau et al., 1999). Two main categories were defined in this framework: (i) general description and the

[9] The detail of the CPWF-PN 25 project is provided at http://www.ecole-commod.sc.chula.ac.th.

structure of the modelling process, and (ii) participants and their involvement through collaborative methodological stages.

The general description was proposed to specify the goal(s) and output(s) of the collaborative modelling process. The analysis of the modelling process structure focused on: (i) key original characteristics, (ii) sequence of methodological steps, (iii) tools & techniques used, and (iv) mode of learning (Table 6.1). The second part was to reveal the type of participants and analyze their respective degree of involvement. Two keys, decision-maker and flow of information between stakeholders and modellers, were defined with 6 degrees of stakeholder involvement ranging from no direct interaction to total control (Table 6.2). The decision-controller refers to the one who decides which information should be transferred or exchanged at a specific stage. For instance, if 'Information' is the degree of involvement, it means that a modeller is transferring his/her information to stakeholders. These levels were analyzed at each of the predefined methodological stages from "problem identification" to "decision on next step".

Goals and outputs found in these case studies range from theoretical testing to RRM problem-solving through the development of different tools for either qualitative or quantitative method or combination of both methods. Tools and techniques used for each case are determined by the goals and outputs (Table 1). The sequence of methodological steps is similar in all cases. Their first step is to identify problems at stake, and gather information for the system identification. Then, the development of models is carried out with stakeholders (Table 1). Finally, models produced are used to reach the defined goals ranging from testing assumptions (Becu et al., 2007; Gonzalez, 2002), to developing a decision support system (DSS) leading to an action plan (Mendoza et al., 2006b; Nico Hjortsø et al., 2005; Tidwell et al., 2004), or combination of theoretical testing and DSS development (Cain et al., 2003).

Table 6.1 General description and the structure of the modelling process of 6 case studies.

Category	Method	Model produced	Problem	Goals and outputs	Structure of modelling process			
					Original characteristics	Tools and techniques	Sequence of methodological steps	Mode of learning
Qualitative	Cognitive Mapping and Soft Systems Methodology	• Thematic cognitive map	• Large-scale of mangrove deforestation	• Develop a facilitative device • Create a detailed understanding of different stakeholders' use of the mangrove	• Develop facilitative device through the integration of element of soft systems and critical system thinking with stakeholders' engagement in the modelling process.	• Stakeholder analysis • Conflict assessment • Problem-structuring (soft systems methodology): Cognitive map and qualitative questions • Critical systems thinking • Cognitive map software package "Decision Explorer"	• Gather information • Produce specialist cognitive map • Interview planning • Producsetakeholders' cognitive map. • Final analysis to carry out produce a new cognitive map for developing facilitative device	• Single loop learning: many participants involved during the problem identification, and exposure of the existing and potential conflicts but no further stakeholders' participation was organized.
Quantitative	System Dynamics	• Causal loop diagrams • A system dynamics (SD) model	• Imbalance between water supply and demand • Lack of stakeholder involvement in making development plan	• Create a water resources model to assist in community-based water planning	• Many presentations of interim versions of the SD model to allay the disparity in understanding between modellers and the public	• Causal loop diagrams and software package "Studio Expert 2001 and 2003" • Conceptual model represents dynamic water budgets of interaction between surface water and groundwater stored in the basin	• Define problem and the scope of analysis • Development of a description of the system in casual loop diagrams • Casual loop diagrams to system dynamics context conversion • Model review • The use of model by the public	• Multi-learning loop: different tools used (causal loop diagrams used to understand the system and a SD model used to explore scenarios). No furhter iterative participation was indicated.
	Multi-Agent Systems	• An agent-based model (ABM)	• The conflicts between upstream and down stream villages has took place as a result of water scarcity.	• Test assumption whether stakeholders can be confronted directly with an abstract computer model and use it for scenario exploration	• Direct confrontation of stakeholders with the ABM. • Examine the socio-political issues (on negotiation and collaborative decision-making) linked to the use of ComMod	• "Field work" for "primary data collection for model calibration". • "Field work" for subsequent interactions with stakeholders "to refine the model" during participatory simulation sessions • ABM as a tool to facilitate communication among stakeholders	• The Companion Modelling (ComMod) involves an iterative feedback loop ("field work" -> "modelling" -> "simulation") between researchers and stakeholders	• Multi-learning loop: three participatory sessions focusing on co-learning through collective discussion
	Multi-Criteria Analysis	• A model integrating Multi-Criteria Analysis (MCA) with system dynamics (SD) model	• Conflicts of interests between state agencies trying to protect the forest and local communities exploiting the forest	• Increase participation of local communities in forest management throguh a group model building	• A development of integrating MCA with SD model was conducted under participatory modelling process with iterative, cyclic and iterative within and among five steps process	• SWOT strategic planning and MCA • Cognitive mapping • A computer-assisted model called "Co-View software" to transform cognitive maps to a SD model	• Identification and exploration of the problem • Soft or qualitative value elicitation • Model building with implementation of MCA • Use of model with MCA capability • Development of an action plan	• Multi-learning loop: iterative modelling process to develop an action plan
	Probability and Statistical method	• Cause and effect relationship diagrams • Bayesian Networks (BNs) flow diagrams	• Agricultural policy makers need a decision support system (DSS) to identify problems and assess feasible and practical farm management solutions for farmers.	• Test BNs if it can be accessible to non-specialists and able to provide generic, flexible framework for the construction of a DSS.	• Enhance participatory analytical capacity by integrating a quantifiable tool (BNs) into participatory process to develop a decision DSS.	• Cause and effect relationship diagrams • BNs flow diagrams	• Identify the problems: Express problems as objects (nodes) • Give value to each problem object • Discuss potential solution objects • Give value to each solution object • Construct a diagram showing the cause and effect relationships • Discuss and give values to any other things that the proposed solutions will affect • Evaluate the likely degree of impact of each solution in numeric terms	• Single learning loop: local farmers • Multi-learning loop: government officers planed to reuse BNs model as a DSS.
	Spatial Mapping	• GIS map integrating folk GIS	• Decline of traditional workgroups to conserve the unique handcraft paddies terraces	• Integrate spatial analysis capability and people's knowledge of their own space.	• GIS makes available real-world data to others and help discuss and build a common view	• Aerial-photographs of 1951 (scale 1:40,000) and 1980 (scale 1:60,000) • SPOT image (20 m solution) • Scanned topographic map of Ifugao (scale 1:50,000) • ILWIS was the available GIS software.	• Step 1: Establishing boundaries • Step 2: Re-tracing the "water district" • Step 3: Participatory image interpretation • Step 4: Provincial link-up	• Single learning loop: No furhter iterative participation was indicated.

Table 6.2 Participants and their involvement in 6 case studies at each of the modelling stages.

Category	Method	*Participant to modelling process*										
					Degree of involvement							
		Selection method	*Diversity*	*Number*	*Problem identification*	*Preliminary synthesis / diagnosis & data collection*	*First design of conceptual model*	*Model implementation*	*Definition of scenarios*	*Scenario exploration*	*Decision on next steps*
Qualitative	*Cognitive Mapping and Soft Systems Methodology*	• Key institutions and informants involved in the planning and management of the zoning strategy	Damdoi Forest Enterprise (DFE)	2	4	4	4	4	4	4	na
			Coastal management specialists	2	4	4	4	0	4	4	na
			Government agencies	2	4	4	0	0	4	4	na
			Farmers (agriculture-fishery farming)	7	4	4	0	0	4	4	na
			Landless people	2	4	4	0	0	4	4	na
			Small-scale agriculture	1	4	4	0	0	4	4	na
			Fruit producer	1	4	4	0	0	4	4	na
			Bag-net fishermen	2	4	4	0	0	4	4	na
			Near-shore fishermen	2	4	4	0	0	4	4	na
Quantitative	*System Dynamics*	• Key institutions involved in the development of water planning model	Sandia National Laboratories (SNL)	na	0	0	4	4	4	4	na
			the Middle Rio Grande Water Assembly (MRGWA)	na	4	4	4	4	4	4	4
			the Mid Region Council of Governments (MRCOG)	na	2	2	0	0	4	4	na
			the Utton Transboundary Resource Center	na	0	0	0	0	0	5	na
			Public	na	0	2	0	0	4	4	na
	Multi-Agent Systems	• Farmers from upstream and downstream village, village headmen, representatives of the TAO and the manager of water company.	Northern Thai farmers / lowland irrigation water user	na	2	2	0	4	4	4	4
			Hmong ethnic farmers / upland irrigation water users	na	2	2	0	4	4	4	4
			Village households / domestic use of water	na	2	2	0	4	4	4	4
			Drinking water company / industrial use of water	na	2	2	0	4	4	4	4
	Multi-Criteria Analysis	• Based on at least 10 years working experience within the Mafungautsi Forest	District foresters	2	4	4	2	4	5	4	na
			Agricultural extension officer	1	4	4	2	4	5	4	na
			Social scientist	1	4	4	2	4	5	4	na
			Provincial officer	1	4	4	2	4	5	4	na
	Probability and Statistical method	• No specific criterion is provided for selection of state agencies. • The participating farmers were invited by field workers from the Department of Agrarian Services to represent the range of farmers and farming activities in the area.	The Irrigation Department	na	5	5	5	5	5	5	5
			The Department of Agrarian Services	na	5	5	5	5	5	5	5
			The Department of Agricultural Development Authority	na	5	5	5	5	5	5	5
			The Department of Forestry	na	5	5	5	5	5	5	5
			The National Water Supply and Drainage Board	na	5	5	5	5	5	5	5
			The Department of Public Administration	na	5	5	5	5	5	5	5
			Representatives from Pradeshiya Sabawas	na	5	2	0	0	0	0	na
			Farmers at the head of the basin	9	5	2	0	0	0	0	na
			Farmers at the tail of the basin	11	5	2	0	0	0	0	na
	Spatial Mapping	• No specific criterion is provided for participant selection.	Students	2	2	2	2	4	0	0	na
			Ifugao's farmers	6	2	2	2	4	0	0	na
			Ifugao provincial government board	na	2	2	2	4	0	0	na

na = not available

Degree of stakeholder involvement in modelling process: Bold character represents decision-controller. Arrow represents flow of information.
0 = No direct interaction 1 = Information [Stakeholder ⟵ **Modeller**] 2 = Consultation [Stakeholder ⟶ **Modeller**]
3 = Co-thinking [Stakeholder ⟷ **Modeller**] 4 = Co-designing [**Stakeholder** ⟷ **Modeller**] 5 = Total control [**Stakeholder** ⟷ Modeller]

In the CM, a single learning loop was found. Many participants were involved during the problem identification, and exposure of the existing and potential conflicts, in order to produce the facilitative device. In the case of the SD, multi-learning loop was likely to happen through many presentations of interim versions of the model. Multi-learning loop was also found in the MAS case because of the repeated use of the same model that was improved according to stakeholders' comments. In the MCA case study, multi-learning loop was generated because the iterative modelling process was conducted to develop an action plan.

Two learning modes were found in the probability and statistical method using BNs. The policy makers could be facilitated to use BNs to build a DSS while farmers could not. As a result, the policy makers planned to carry out more BNs experiments enabling them to have multi-learning loops. In the case of static representation of the system using GIS, the learning process was limited to only a single learning loop as a result of the difficulty in exploring future scenarios through the model produced.

The different types and degrees of stakeholder involvement in each modelling stage play an important role in justifying how far the selected method participating stakeholders are engaged in the modelling process. A synthetic illustration of six case studies was produced to address the relationship between types of stakeholders and degrees of their involvement at each modelling stage linking to the methods used (Figure 6.2). The participants were classified into decision-makers and lay people, or public involvement. Based on table 6.2, farmers and fishermen are considered as lay participants. Participants working for government or academic institutes are categorized as decision-maker participants. In the case of decision-maker participants, multi-degree of involvement was often found, for instance "no direct interaction" and "consultation" at problem identification stage. In such a case, only higher degree of involvement was kept; hence, "no direct interaction" was dropped off.

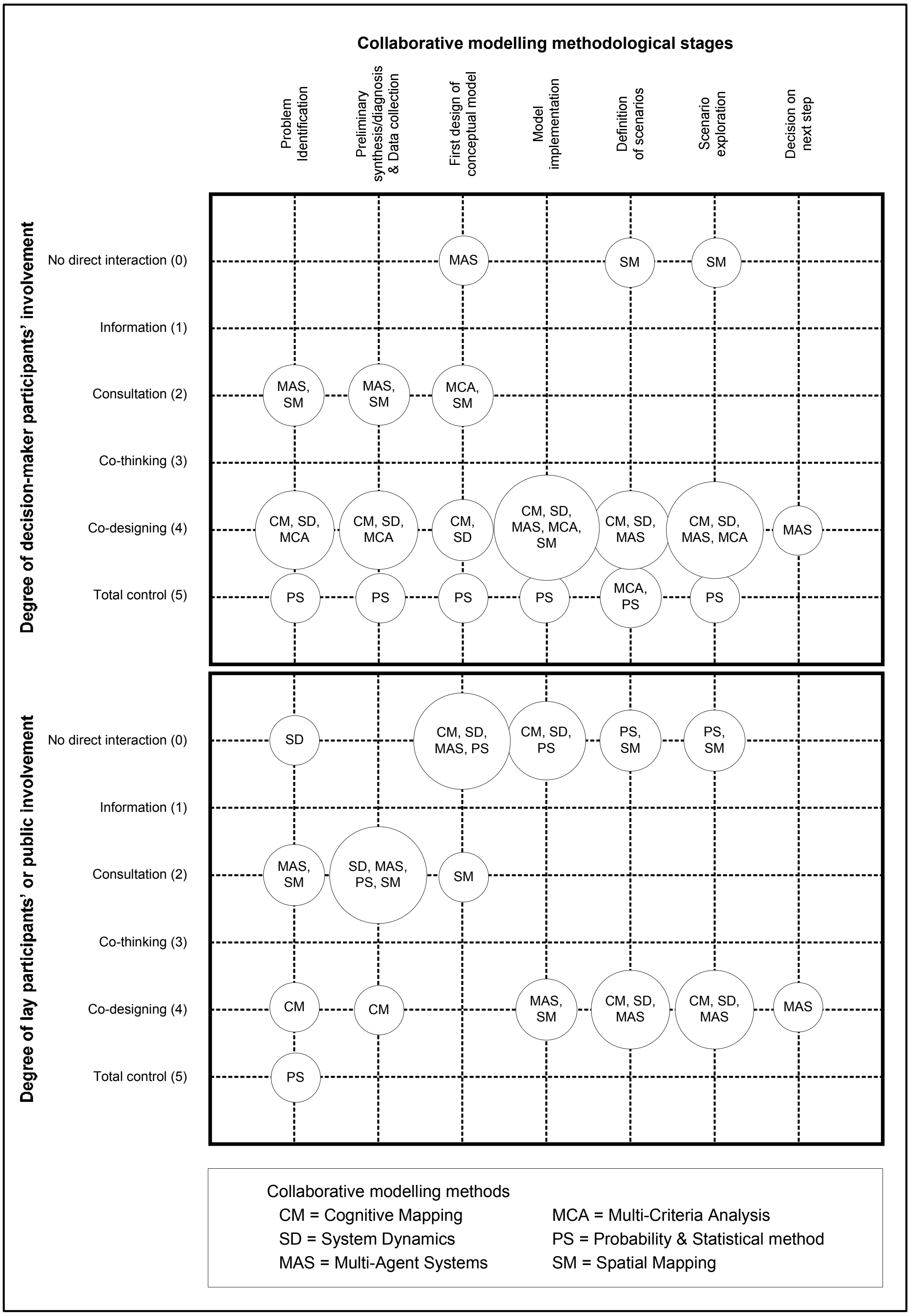


Figure 6.2 Relationship between types and degrees of stakeholder involvement in 7 collaborative modelling methodological stages found in 6 collaborative modelling methods.

In this analysis, lay people or public involvement is not identified in the MCA case study. Regarding the degree of involvement, the flow of information controlled by the modeller and the co-thinking defined as a two-way information flow controlled by the modeller are not presented in any case (see ‘Information’ and ‘Co-thinking’ in Figure 6.2). This indicates that the modellers had no absolute control in these six collaborative modelling processes. But the modeller can control which information is useful to be obtained. In this case, participants play a consultant role as found in the ‘Consultation’ (Figure 6.2).

Both lay and decision-maker participants of MAS and SM methods hold consultations to identify problems (problem identification). The consultation may indicate the need for modellers to better understand the context of problems prior to moving forward to the next stage. For other methods, participants engage in two way information flow either ‘Co-designing’ or ‘Total control’, whereby stakeholders are decision-controllers. Due to the simple causal diagrams found in the CM and range of variable values determined in probability and statistical methods (PS) using BNs, these features are not so difficult for the participants to engage in. Only the SD reported no direct interaction between the modeller and lay or public participants.

For the preliminary synthesis/diagnosis and data collection, the involvement of decision-maker participants is not different from the problem identification stage. For the lay participants, CM was used to get them involved at co-designing, while consultation was found in other methods. This may indicate that most collaborative methods are often used to gather data from lay participants at this modelling stage. During the problem identification and preliminary synthesis/diagnosis & data collection, the causal loop diagram is often used to structure problems derived from collective agreement among participating stakeholders. The joint use of CM, SD and MCA is an effective method. The CM is initially made on a piece of paper with simple casual diagrams while maps are used in SM. These features easily allow for lay people to get involved.

At the first design of a conceptual model, the decision-maker participants seem to have different degrees of involvement. However, it is different for the lay participants who are not involved (no direct interaction) in this stage except for SM. The non-participation of lay people at this stage may be caused by the difficulty of the tools used for communication with lay people (often computer software) when the initial conceptual model is produced. But the SM used maps, which are more easily understood by lay people.

Once the modelling process reaches the model implementation stage, the lay participants are often left out in all methods. Only MAS and SM is used with lay participants to implement the model by exchanging information with an equal amount of controlling power (both are decision-controllers). This is a critical stage that all participants should take part in as participation in this stage could help them to understand the model and lessen the “black box effect”. The sense of co-ownership could also be effectively built through this stage. Furthermore, the model co-constructed with participants consistently proves its validity. This validity is important before moving to the scenario identification and exploration. With the simulation capability of methods such as MAS and SD, lay people are able to participate in defining scenarios and scenario exploration. Without simulation, CM is likely to stimulate participants’ creativity through imagination in definition of scenarios and scenario exploration. Only the paper about MAS reported the next step (Decision on next step) decided by the modeller and participants. The MAS also shows all participants taking part in all stages equally. As a consequence, the gap between participants generated from partial participation is not likely to occur.

However, as stated by Asselt et al. (2002), there is no best method to conduct group model building; it is preferable to think about collaborative modelling as a flexible approach where a facilitator can make selections from a toolbox which contains many methods and tools to guide the process. In my case, the Companion Modelling (ComMod) approach is used. Throughout the process, the conceptual model representing interactions between land & water use and labour migration is enriched as a consequence of the development of associated tools, namely a Role-Playing Game (RPG) and ABM, with local participants. This ComMod process aims to enhance dialogue between researchers and participating farmers, integrate local and scientific knowledge, and build a shared representation of the system under study where researchers themselves pose as stakeholders in the system.

CHAPTER 7
COMPANION MODELLING APPROACH AND METHODOLOGY

In the field of integrated renewable resource management (IRRM), complexity and problems are consequences at macro level emerging from diverse individual human-environment interactions. Understanding such interactions, particularly from the demand side or resource users, is needed to discover a practical development that is likely to be accepted and adopted by concerned users. However, this understanding varies due to multiple stakeholders (scientists, decision-makers, and different local resource users etc.) with different objectives, perceptions, interests etc. and involvement at multiple scales (individual and institutional level). Building a shared representation of a complex system focusing on problems being examined among these stakeholders is an important stage prior to launching an IRRM program.

The companion modelling (ComMod) approach for renewable resource management (RRM) is a highly interactive collaborative modelling process. For the ComMod process, such a shared representation can be constructed by researchers in collaboration with local stakeholders through a continuous co-learning, knowledge exchange and dialogue enhancement. Through the process, stakeholders better understand each other as well as becoming more comprehensive in their investigations into problematic situations. Based on such a shared representation, possible solutions of their choice can be collectively identified and explored through the use of simulations (Trébuil, 2008). Through the process, trust among stakeholders is also built leading to the development of more practical and acceptable IRRM. In this chapter, I present the origin of ComMod, its methodology, and recent topics of concern and interest regarding the ComMod approach and its use.

7.1. Origin of Companion Modelling

Since 1993, the GREEN research team (management of renewable resource and environment) founded by Dr. Jacques Weber has been developing modelling activities to better understand the interactions between social and ecological dynamics. This group of researchers considered that the existing methodologies of the 1980s to study IRRM were always drawn from either the angle of “an ecological system subjected to anthropologic disturbance” by ecologists, or the angle of “a social system subjected to natural constraints” by economists. GREEN research team looks at IRRM in a more integrated and inclusive way through the design of a trans-disciplinary research approach that investigates the co-viability of ecological and social dynamics by eliciting key interactions among heterogeneous stakeholders having diverse interests, perceptions and decision-making processes on a given problem (Figure 7.1).

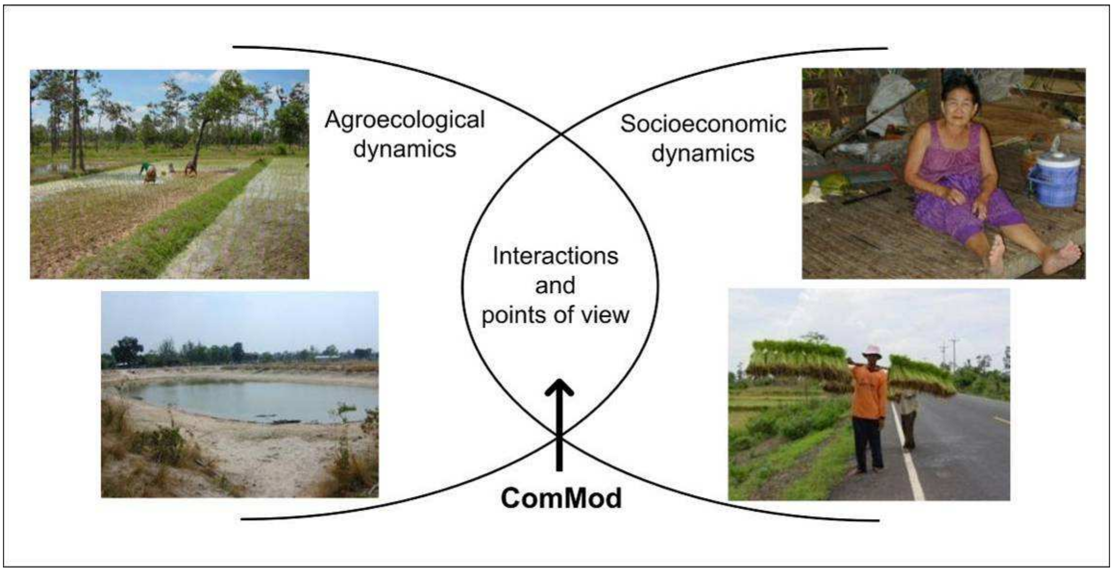
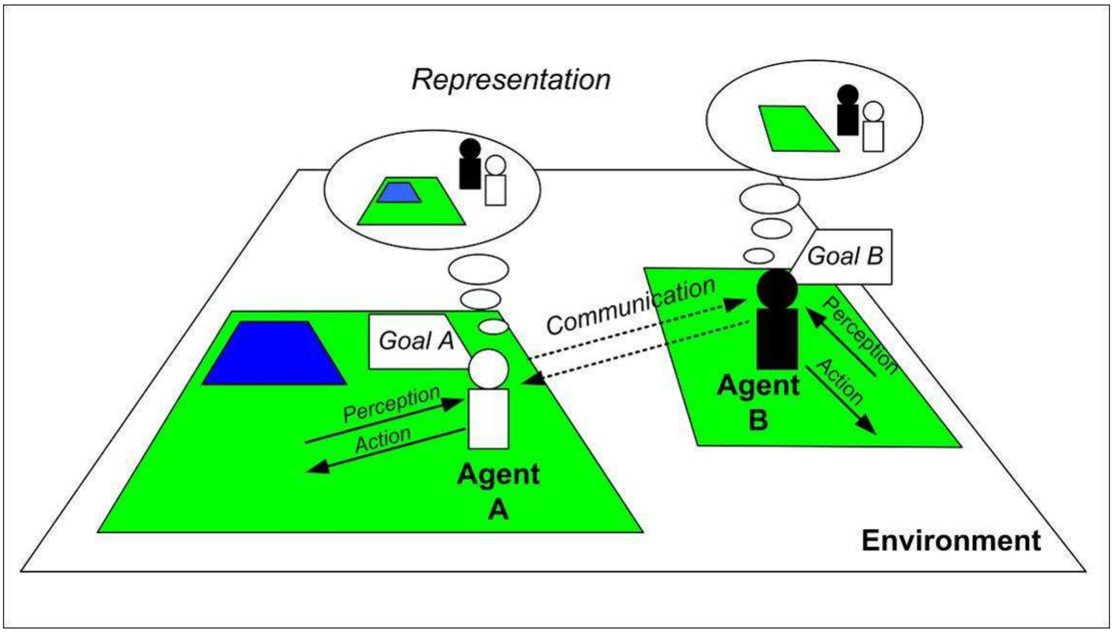


Figure 7.1 Schematic representation of the focus of ComMod.

The researchers’ objective is to try to understand the interactions between these key processes. Because of the complexity of current RRM problems and the rapidity of change, system modelling needs to be used at a time when innovative powerful tools emerging from computer science are available to represent human-environment systems and simulate their co-evolution (Trébuil, 2008). Through the construction of a model, knowledge sharing between stakeholders can be facilitated leading to the integration of knowledge from various sources.

This team selected Multi-Agent System (MAS), a domain of distributed artificial intelligence, to develop their modelling tools because the MAS concept also focuses on interactions among different agents who have different representations of the common system to be managed (Figure 7.2). An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its designed objectives. An agent can be described as autonomous because it has capacity to adapt when its environment changes (Wooldridge, 1999). The coordination of actions or the construction of systems are consequences of interactions between relatively independent and autonomous agents, which operate within communities in accordance with what are sometimes complex modes of operation, conflict and competition in order to survive and perpetuate themselves. Organized structures emerge from these interactions, which in turn restrict and modify the behaviours of the agents (Ferber, 1999). MAS can simplify problem-solving by dividing the necessary knowledge into subunits, by associating an intelligent independent agent to each subunit, and by coordinating these agents' activities (Bousquet and Le Page, 2004).



Source: adapted from Ferber 1999.

Figure 7.2 Schematic representation of a Multi-Agent System.

Historically, one of the first ComMod experiment was carried out in Senegal River valley to study the viability of irrigated systems with a scientific model (SHADOC) presented to local farmers as a RPG (Barreteau et al., 2000). The core purposes were to understand how different coordination patterns among heterogeneous stakeholders affect the viability of their common irrigated system, to encourage them to discuss their irrigation schemes, and to support the improvement of coordination within irrigated systems. The conceptual model, SHADOC, was translated into three different artefacts aimed at specific purposes.

To better understand the dynamics of the system, the conceptual model was implemented into the computer-based MAS-SHADOC, also called SHADOC. It was designed to simulate scenarios with different operational rules in an irrigated system. To introduce it to rice growers, the SHADOC model was translated into an RPG, thus fulfilling a second purpose: to communicate the content of the conceptual model with concerned stakeholders. Afterwards, another computer MAS was developed based on the structure and rules implemented in the RPG. It aimed at testing the possibility of using it as a negotiation tool in a group discussion leading to the formulation of collective rules for the collective management of an irrigated system. In this experiment, the RPG opened the black box (Barreteau, Bousquet et al., 2001) in MAS simulations while MAS simulations allowed participants to better understand the overall behaviours of the system under different conditions.

Following the SHADOC case study, the SelfCormas experiment was also conducted in Senegal (d'Aquino et al., 2003) as a collective conception of the model that aimed to facilitate discussion on decentralized land allocation issues among local and representative stakeholders. This time, the main objective was to test directly the design of these modelling tools by stakeholders, with as little prior design work by the modellers as possible. First, players designed a game according to their own representation of their territory. The "self-design" experiments were organized in field workshops. Then researchers were able to organize a gaming session to help participants simulate a scenario by using their self-designed RPG.

These two experiments demonstrated the potential for the joint-use of RPG and ABM. This combining of the associated tools (RPG-ABM), in interaction with field work in a collaborative modelling process aiming to facilitate stakeholders' knowledge exchange about IRRM in complex systems was called “Companion Modelling” (ComMod) by the GREEN research team.

In Thailand, ComMod and Integrated Natural Resource Management (INRM) was first introduced in late 1998 with the first training course in Asia organized by CIRAD at the Multiple Crop Centre (MCC), Faculty of Agriculture, Chiang Mai University. Following this first training course, several short training courses sponsored by CIRAD, IRRI and the Asia IT&C program of EU were organized in Thailand. Researchers and lecturers from different academic backgrounds working in South and Southeast Asian countries participated in these workshops. Several of them decided to apply the ComMod approach in their research projects.

The first ComMod case study in Thailand looked at land use change due to the expansion of sugarcane plantation in upper paddy fields of Nam Phong district, Khon Kaen province (Suphanchaimart, Wongsamun et al., 2005). Another pioneer case study was conducted in the Akha village of Mae Salaep of Mae Fah Luang district, Chiang Rai province. In this experiment, a sophisticated MAS model was first implemented by researchers. It was later converted into a simpler RPG to allow local highland farmers to be able to validate the model and to examine the risk of land degradation through soil erosion in parallel with the commercialization of the local farming systems (Trébuil, Shinawatra-Ekasingh et al., 2002).

After several years of experience and the implementation of several case studies on various resource management topics on different continents (Asia, Europe, Australia, Africa), a ComMod network of practitioners was founded in 2003. Its initial purpose was to clarify the scientific posture to define a deontological framework for guiding the correct use of ComMod when dealing with multi-actor processes. The first version of the ComMod charter was published in 2003 (Barreteau, 2003b).

7.2. Companion Modelling Approach

The following section presents the theories related to ComMod. ComMod principles, objectives, methodology and tools used were also explained.

7.2.1. Main Theoretical References

Several theoretical references inspired the development of the ComMod approach and support its operating principles.

7.2.1.1. The Science of Complexity

Complexity is usually referred to a condition of numerous elements in a system with numerous forms of relationships among the elements (Nicolis et al., 1989). Definition of complexity is often tied to the concept of a ‘system’. Complex systems tend to be high-dimensional, non-linear and hard to model. They can be biological, economic and technological systems etc., or in fact, a mixture of them. In a complex system, the properties at macro level emerge from interacting components and therefore, cannot be observed at individual or micro level (Janssen, 2002). The science of complexity highlights that the behaviour of a complex system due to emergence and self-organization is dynamic, uncertain, and unpredictable. The ComMod approach attempts to better understand interactions among system components that cause changes in a complex system, and modify them to explore how to lead the system towards more desired states through simulations. Through the modelling process, ComMod field collaborators (farmers, researchers etc.) are able to adapt themselves to better manage the system once they are facing the changes. Such adaptive management can protect the system from collapse.

7.2.1.2. Resilience and Adaptive Management

The definition of resilience can be considered in two disciplines. First, the engineering resilience refers to efficiency, control, constancy, and predictability - all attributes at the core of desires for safe and optimal performance. The second definition of ecological resilience focuses on persistence, adaptiveness, variability, and unpredictability - all attributes embraced and celebrated by those with an evolutionary or developmental perspective. The Canadian ecologist C. S. Holling emphasized the differences between these two definitions as tradeoffs between efficiency on the one hand and persistence on the other, or between constancy and change, or between predictability and unpredictability. Resilience is defined as the capacity that an ecosystem can tolerate the disturbance without collapsing and return to a single steady or cyclic state. This definition of resilience assumes that behaviour of a system remains within the stable domain that contains this steady state.

Resilience is conferred in human and ecological systems by adaptive capacity, which, in ecological systems, is related to genetic diversity, biological diversity, and the heterogeneity of landscape mosaics (Carpenter and Gunderson, 2001; Gunderson and Holling, 2002). In social systems, the adaptive capacity refers to the existence of institutional social networks that learn and store knowledge and experience, create flexibility in problem solving and balance power within and among social groups

(Berkes, Colding et al., 2003). Adaptive management identifies uncertainties, and then establishes methodologies to test hypotheses concerning those uncertainties (Walters, 1986). Several managing tools are used not only to change the system, but as tools to learn about the system. The need for learning and the cost of ignorance are major concerns, while traditional management is focused on the need to preserve and the cost of knowledge. Adaptive management implies flexibility, diversity, and redundancy in regulation and monitoring activities leading to corrective responses and experiential probing of the ever changing circumstances of a SAES.

Resilience can be achieved by an adaptive management capacity that can determine how vulnerable the system is to unexpected disturbances and surprises that can exceed or break the system. (Holling, 2001). ComMod was inspired by the adaptive management approach, recognizing that adaptive capacity is dependent on knowledge generated by a co-learning process: essentially, through free exchange among different actors (Bousquet and Trébuil, 2005). Therefore, such knowledge exchange can result in the integration of diverse points of views. Through the co-learning process, a proposed management model can be collectively agreed upon among multiple actors.

7.2.1.3. Collective Management of Multi-actor Processes

Collective action is the pursuit of a goal or set of goals by more than one person. It is a term that has formulations and theories in many areas of the social sciences. Theories of collective action emphasise how group behaviour can, in some sense, be linked to social institutions. Collective action, or “actions taken by two or more people in pursuit of the same collective good” are typically framed as resulting in some shared outcome, or public goods (Bimber, Flanagin et al., 2005). ComMod emphasizes coordination and negotiation mechanisms among stakeholders through continual collective exchange and learning processes through interactions within social networks; from such interactions, solutions emerge. The knowledge is also constructed through the collective learning processes as defined in constructivism.

7.2.1.4. Constructivist Epistemology

Constructivism is an epistemology supporting the learning process, and views all of my knowledge as "constructed". It assumes that reflecting any external "transcendent" realities is not necessary, and convention, human perception and social experience is contingent. The common thread between all forms of constructivism is that they do not focus on an ontological reality, but instead on the constructed reality. Reality appears as something actively constructed (Röling et al., 1998) and is often perceived and managed differently by individuals depending on their perceptions of the environment, which in turn may lead to conflicts. ComMod realizes the importance of different stakeholders' perceptions when looking at a common IRRM problem. ComMod attempts to integrate not only various scientific disciplines, but also the various points of views of local stakeholders into a shared representation regarding the problem at stake through a communication and social learning process.

7.2.1.5. Post-normal Science

Post-normal science characterizes a methodology of inquiry that is appropriate for cases where "facts are uncertain, values in dispute, stakes high and decisions urgent"(Funtowicz and Ravetz, 1993). It is primarily seen in unpredictable long-term issues where we possess less information than we would like. Post-normal science postulates that works (research, development of action plans etc.) based exclusively on scientific knowledge under normal science cannot deal with conditions of high uncertainty. It is necessary to promote the communicative rationality on the basis of shared learning, collaboration, and the development of consensus about action to take between experts and local people (Röling et al., 1998). The role of interdisciplinary teams, including natural and social scientists, is to understand and strengthen collective decision-making processes through a platform of interactions among stakeholders. ComMod takes into account such roles to support the integration of interdisciplinary knowledge from diverse sources (local, expert and scientific ones). In the ComMod approach, shared learning between stakeholders is supported through the use of mediation tools such as RPG and ABM that evolve through the collaborative modelling process. As a consequence, stakeholders better understand their situation and each other, and a common representation about problems being examined by stakeholders is also developed through the evolving mediation.

7.2.1.6. Patrimonial Mediation

The patrimonial approach is defined by Ollagnon (1991) as “all the material and non-material elements that work together to maintain and develop the identity and autonomy of their holder in time and space through adaptation in a changing environment”. Patrimonial mediation contributes to the understanding and practice of co-management of renewable natural resources. Mediation is a negotiation approach that brings in a neutral party to facilitate agreement among different parties in conflict. From the patrimonial mediation approach, ComMod was influenced by the importance given to its analysis of a system’s evolution in the search for acceptable solutions to common problems.

7.2.2. Principles and Objectives of ComMod

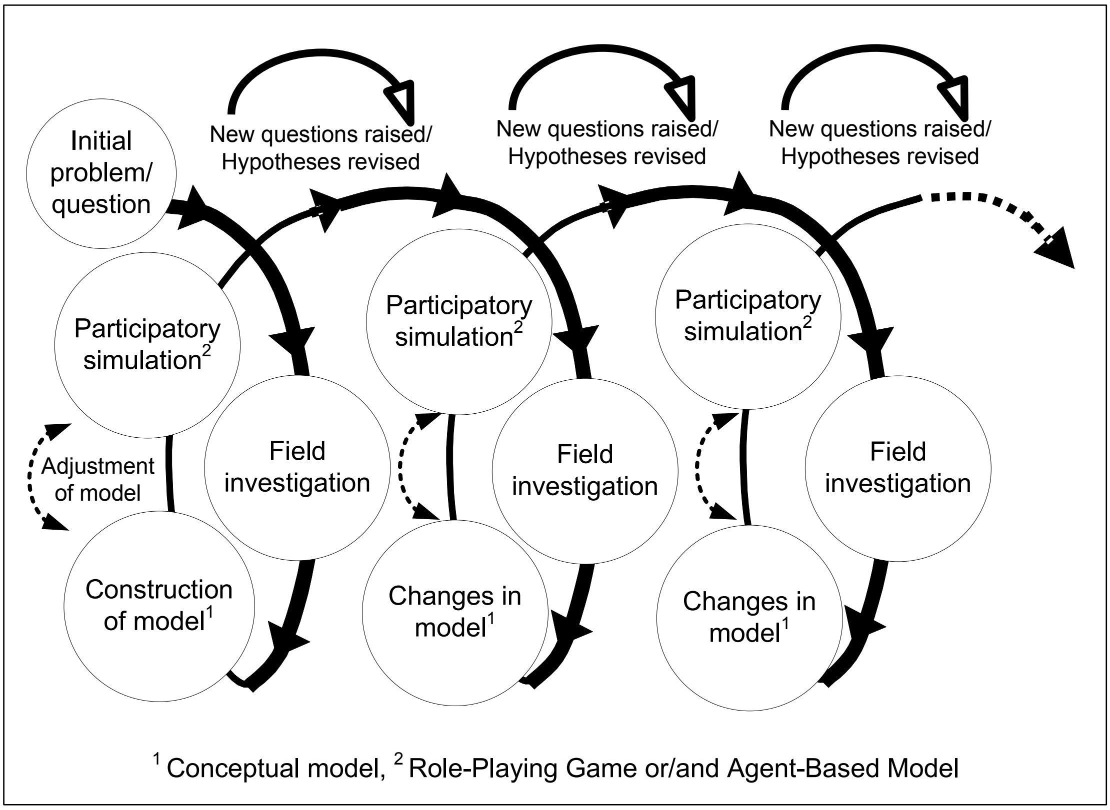
7.2.2.1. Fundamental Characteristics of ComMod Approach

a. Researchers’ posture:

ComMod is an action-oriented research approach that always involves multiple stakeholders throughout the process to ensure that the diverse perceptions of a given common RRM problem are included. Because we are dealing with complex and very dynamic research objects, which are uncertain, and consist of multiple and legitimate points of view, the ComMod researcher becomes an actor of the system under study, and a facilitator of exchange among participating stakeholders. The researcher plays a dual role: (i) to generate new knowledge on a system or on the ComMod approach itself, and (ii) being an actor of the system, to improve it through changes in the stakeholders’ perceptions, interactions, and actions (Trébuil, 2008). Therefore, the ComMod researcher needs to avoid the risk of manipulating local actors, or being manipulated by them. To respond to such concerns, the ComMod charter recommends the systematic monitoring of the effects and impact of ComMod activities, and the hypotheses made in the ComMod process should be transparent and explicit to all participating stakeholders.

b. A back and forth iterative and continuous process between laboratory and field activities:

ComMod calls for continuous and iterative confrontation between theory and reality. It is based on iterative back and forth phases between the laboratory (model implementation), and field activities (interviews, specific field surveys, and/or participatory modelling and simulation workshops) generating a succession of evolving loops (Figure 7.3).



Source: adapted from Barnaud, 2006.

Figure 7.3 Representation of a ComMod process.

There are three main stages in a ComMod process that can be repeated as many times as needed (Bousquet et al., 2005).

1. Field investigations and a literature search supply information and help to generate explicit hypotheses for modelling by raising a set of initial key questions to be examined by using the model.
2. Modelling, that is, the conversion of existing knowledge into a formal tool to be used as a simulator.
3. Simulations, conducted according to an experimental protocol, to challenge the former understanding of the system and to identify new key questions for new focused investigations in the field.

7.2.2.2. Dual Objectives and Specific Contexts of the ComMod Approach

When practicing the ComMod approach, two objectives are: (i) to develop simulation models integrating various stakeholders' points of view to improve understanding of interactions related to a RRM problem being studied; and (ii) to use simulation models within the context of platforms for collective learning to facilitate dialogue among multiple stakeholders, and support coordination and negotiation processes leading to collective decision and action plans to mitigate RRM problems. Thus, ComMod can be used in two specific contexts.

a. Knowledge production on a complex system:

The context of knowledge production depends on a special relationship between actual circumstances in the field and the model. Such knowledge can be built through the co-construction of a shared representation of the system in forms of models. These models can be conceptual ones, represented by diagrams, RPGs, ABMs, or a combination of various types. In general, the researcher starts by formalizing the existing knowledge to diagrams called Unified Modelling Language[10] (UML) (Fowler, 2004). These UML diagrams are subsequently implemented into RPGs and/or ABMs that are used by research teams to facilitate group model building among stakeholders. The discussions lead to new knowledge and questions, forcing the researcher to revise his/her initial hypotheses and enrich the conceptual model. This cyclic process generates a family of models representing the outcomes of repeated interactions between researchers and field collaborators. Models also aim at seeking mutual recognition. Such mutual recognition is gradually and collectively perceived during the model implementation in the collaborative modelling process.

b. Facilitation of collective decision-making in a complex system:

This second specific context implies methodological research to facilitate the joint management of a complex system. ComMod intervenes upstream of any technical decision to support the deliberation of concerned actors towards the production of a shared representation of the problem at stake. Based on such a shared representation, stakeholders are able to identify possible collective management to

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[10] The Unified Modelling Language (UML) is a family of graphical notations, backed by single meta-model, that help in describing and designing software systems.

mitigate the problem. The ComMod process tries to support the management of ecological and social uncertainty by local actors. While guiding them towards an agreement on desirable long term objectives through the collective exploration of scenarios, it prepares them to be ready to adjust their behaviour and actions on the way, in agreement with the principles of an adaptive management approach. ComMod does not include the other possible steps of the mediation process, particularly those dealing with more quantitative expertises (Bousquet et al., 2005).

7.2.3. Main ComMod Methodological Steps in Association with Key Tools Used

The ComMod methodological phases, and choices of tools used are, in fact, very flexible. Five phases presented in this section are commonly implemented. But it is not obligatory for ComMod practitioners to exactly follow these phases. Adjustment and rearrangement may happen depending on the context of each case study at a given time, and on the evolution of the process.

7.2.3.1. Initialization of a ComMod Process

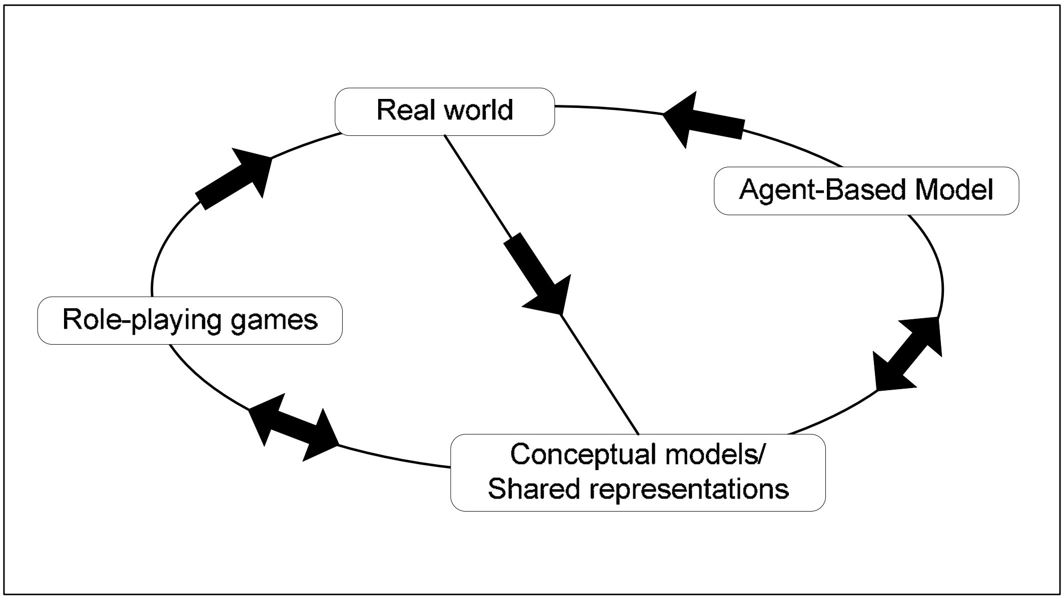
Stakeholder involvement is needed as early as possible, even if it is in the initial stages prior to launching the ComMod process. First, definitions of problematic issues or questions to be examined have to be precisely defined. Then, it is beneficial for the researchers to acquire from stakeholders enough information about human-environment interactions related to the defined problems and questions formulated in the first step. This information also fills gaps in the researchers' knowledge. At the same time, stakeholders are also clearly informed about the types of activities that they are about to engage in the ComMod process. Moreover, this initialization provides a chance for the researchers to be more conversant with potential future participants in the ComMod process. Several techniques (agrarian system diagnosis, stakeholder analysis etc.) are used to establish such a preliminary knowledge, and mutual trust. These preliminary findings during the initialization are useful to formalize an initial conceptual model, and to select appropriate participants for the subsequent ComMod process.

7.2.3.2. The Co-construction and Conceptualization of Models with Stakeholders

This step is considered the entry point of the ComMod process that usually starts from conceptualization followed by the construction of a RPG and ABM. The preliminary knowledge is usually elucidated in the conceptual model through the use of UML diagrams. UML diagrams have proved that they are useful in encouraging participants to exchange their arguments. UML diagrams are a family of graphical notations, backed by a single meta-model, that help in describing and designing software systems, particularly software systems built using the object-oriented (OO) style. Furthermore, UML diagrams are useful to verify whether the model implemented is working (Fowler, 2004; Rumbaugh, Jacobson et al., 1999). UML diagrams are grouped into two main types: static and dynamic diagrams. The structure and relationship between components in a system is usually represented by a static UML class diagram. Meanwhile, the dynamic part of the system such as decision-making processes is often depicted by UML sequences and/or activity diagrams.

7.2.3.3. Implementation and Validation of ComMod Models

Based on the initial conceptual model, a simple RPG or/and ABM are implemented to be used in gaming or /and participatory simulation sessions (Trébuil, 2008). Figure 7.4 shows the linkage and cyclic use between RPG and ABM in ComMod methodology. A number of studies have employed RPG as a mediation tool to synthesize stakeholders' perceptions toward the current situation including decision-making rules to accomplish a given task under a given environment assigned in the game. Outputs from the game are used for validation and improvement of the model. The model is then used as a tool for scenario exploration with stakeholders. Neither the types of tools, nor sequence and number of their use is restricted in the ComMod methodology. Other tools like GIS, surveys, interviews, debate, and small focus group discussion, are also used as needed. Different combinations of tools are used depending on the objectives set for a field activity. In general, the RPG is used when the objective is to examine interactions among participants, and data acquisition, while the ABM is usually used for data elicitation, and scenario exploration.



Source: Barreteau, 2003b.

Figure 7.4 Linkage between actual circumstances, the conceptual model and its use in role-playing games and agent-based models in the ComMod approach.

Regarding model validation purposed by Gilbert (2008), two areas need to be examined when validating models: (i) the fit between a theory and the model of that theory, and (ii) the fit between the model and the real-world phenomenon that the model is supposed to simulate. The first one is evaluated by comparing the distribution of expected simulated results with a variety of parameter settings to a number of propositions about the form of the relationships expected between variables derived from theory used. Comparing the model and empirical data is another validation technique. In cases where abstract models[11] , whose objective is the development of theory, are used, no empirical data are needed to compare with the model. For the middle range models[12], the criterion is if the simulation generates outputs that are qualitatively similar to those observed in the social world. It is only

[11] Abstract models aim to demonstrate some basic social process that may lie behind many areas of social life. These models are not intended to be used as empirical descriptions of any real-world phenomenon. They are seen as part of the process of the development of a theory

[12] Middle range models aim to describe the characteristics of a particular social phenomenon, but in a sufficient way that their conclusions can be applied widely, rather than just one set of circumstances. The generic nature of these models means that it is not usually possible to compare their behaviours exactly with any particular observable instance. Instead, one expects to be satisfied with qualitative resemblances.

the facsimile models[13] that require empirical data to be compared to simulations. In this case, the model is the regression equation which computes the predicted values of the dependent variable. Models implemented through a ComMod process are often classified as middle range models.

RPGs and ABMs are the most frequently used tools, usually in association, because of their similarities derived from the same conceptual model. RPGs and ABMs are particularly well-suited to representing complex situations and doing prospective studies, as they are able to incorporate randomized and somewhat unpredictable dynamics. Actually, RPGs are models of actual situations, and they are much closer to reality and easier for people to use than ABMs. However, RPGs are rather cumbersome to build and operate, quite costly to use, and cannot be used to provide continuous support in evolutionary decision-making processes. Moreover, RPGs do not allow the set up of sufficiently incremental and iterative processes that progressively integrate new information and knowledge. Thus, RPGs are usually used to help participants engage in the design of the model as well as to facilitate their understanding of ABMs to be used later for simulations.

The RPGs are thus able to simulate scenarios that are imagined by participants and to generate group discussion of possible interactions between users and resources. ABMs are used to explore issues more rapidly and systematically, with the richer and more incremental processes. Based on the SelfCormas experiments RPGs were tested as a progressive way of designing novel ABMs that are more suitable for integrating perceptions of the people involved.

Because of the similarities between these two tools, it is possible for participants to relate to the RPG to ABM and the system under study. Playing games can help participants to understand the structure and operations implemented in the ABM, and reduce its “black box effect” for participants. Table 7.1 summarizes the importance of the initial conceptual model and proposes a classification of situations based on mode of association between the conceptual model, the RPG, and the ABM.

[13] Facsimile models are intended to provide a reproduction of some specific target phenomenon as exactly as possible, often with the intention of using it to make predictions of the target’s future state, or to predict what will happen if some policy or regulation is changed.

Table 7.1 Classification of types of joint use of an agent-based model and of a role-playing game based on the differences and similarities of their conceptual models and time of use.

The conceptual model is	*Different*	*Same*
ABM and RPG are used at the same time	• ABM supports the game • ABM included into the game • The game is a communication tool between ABM and reality	• The game is the model
ABM and RPG are used in succession	• The game helps to learn how to use the ABM	• ABM of the game to replay gaming sessions • Game used to design ABM • Game used to validate ABM • ABM used to design the game • Co-construction of ABM and the game

Source: Barreteau, 2003b

Special attention is drawn to the validation process of the models. Since concerned stakeholders are involved throughout the research process, the co-designed models are consistently and collectively validated by these participating stakeholders. ComMod relies on simulation tools to implement such participatory analyses and scenario explorations, to facilitate individual and collective learning, as well as to mediate conflicts and to engage people in negotiating collective action. Therefore, ComMod models (RPGs or ABM) are mainly seen as short-lived simulation tools built to facilitate communication among stakeholders through the exchange of their multiple points of view and perceptions of phenomena on a given issue and at a given time.

7.2.3.4. Scenario Identification, Exploration and Assessment

Through the ComMod process, participants are usually able to relate the virtual world to real circumstances. Their creativity also increases, enabling them to identify interesting scenarios to be simulated to discover their possible choices of RRM. ABMs are favoured in this activity because they are far more time and cost efficient than RPGs for such a purpose. The ABM can run faster, is repeatable, and presents more synthetic outputs (maps, histograms, diagrams spreadsheets, etc.) with better visualization. These benefits leave more time for their joint assessment that is generally organized in either small homogeneous groups of stakeholders, or in a plenary session.

7.2.3.5. Monitoring and Evaluation (M&E) of ComMod Effects and Impact

There is not yet a specific M&E methodology to assess the effects and impact of such highly interactive and dynamic ComMod processes. But during 2006-2008, a project specifically addressing this M&E issue was carried out. This M&E methodology will look at the various ComMod effects on the participants in terms of learning on the system, on oneself and others, and their interdependence, on the ecological and social dynamics, but also on changes in communication (social network), perceptions, decision-making, behaviour, and finally, practices (Gurung, Promburom et al., 2008).

Regarding activities implemented in a ComMod sequence, Le Page proposed a more detailed 12 stage sequence, highlighted in the following box (Box7.1).

Box 7.1 A ComMod sequence with 12 stages.

1. Sensitizing activities: introduction of the ComMod approach to key stakeholders requesting to look into a given development question, and assessment of its suitability and possibility for use in the local context.
2. Definition of the key question to be examined, by the process leaders and, sometimes, other stakeholders as well.
3. Inventory of relevant scientific, expert, and indigenous knowledge available through literature review & complementary diagnostic surveys to fill the gaps.
4. Knowledge elicitation for modelling via surveys and interviews.
5. Co-design of the conceptual model with stakeholders concerned by the question being examined.
6. Choice of the tool (computer-based or not) and model implementation.
7. Model verification, validation and calibration with local stakeholders.
8. Identification and definition of scenarios with local stakeholders.
9. Exploratory simulations with local stakeholders.
10. Dissemination of the outputs to stakeholders who did not participate in the process.
11. Monitoring - evaluation of the effects of the ComMod process on participants (awareness, knowledge, communication, behaviour, decisions, practices, etc.)
12. Training of interested stakeholders on using the tools produced during the collaborative modelling process.

Source: Personal communication with Christophe Le Page, a pioneering ComMod practitioners.

7.3. Current Hot Topics on ComMod

Up-scaling and out-scaling

As a bottom-up approach, ComMod and its tools used often begin to tackle a problem at the individual level to create a shared representation of an aggregation of individuals. Most ComMod case studies are site and context specific. This has brought about robust discussion on the hot topic of dealing with the possible scaling-up and scaling-out the use of ComMod process and tools. Scaling-up is an institutional expansion, based on positive feedback, from adopters (often grassroots organizations) to other key stakeholders (policy makers, donors, development institutions) who have the power to out-scale the process (Prell et al., 2007). Scaling-out is the spread of project outcomes (i.e., changes such as the use of a new technology, a new strategy, etc.) from farmer to farmer, community to community, within the same stakeholder groups. In other words, scaling-up is the process by which policies, norms, mental models, etc., change in such a way as to support a scaling-out (adoption) process.

The possibility to upscale the use of ComMod approach is being examined. A case study in Nan province, northern Thailand, investigated the conflict between the National Park authority and villagers over forest resources, which was so high that they rarely communicated to each other. ComMod and a hybrid simulator (RPG-ABM) successfully initiated the communication between these two groups of stakeholders (Ruankaew, Le Page et al., 2008). The case study has shown that the National Park officers gained an increased awareness of the villagers' circumstances and points of view. Likewise, the villagers learnt about the consequences of the proposed regulations by the National Park, and agro-ecological dynamics and socioeconomic equity issues.

I have observed changes among participating stakeholders who have adopted new strategies or technologies as a result of knowledge exchange among participating stakeholders in many ComMod case studies. However, according to the limitations of M&E of ComMod effects, the pioneering M&E projects were used to systematically examine such changes in some ComMod cases (Gurung et al., 2008). Some cases, such as a conflict over water sharing between upstream and downstream villages in

Bhutan (Gurung, 2006), have indicated successful institutional expansion, a consequence of up and out scaling of the use of the ComMod process and tools.

To successfully generate the up- and out-scale effects, ComMod practitioners often underline the need for more sensitizing activities prior to engaging all concerned stakeholders in a ComMod process. Such sensitizing activities are also important to better facilitate a bottom-up dialogue between less powerful stakeholders and stakeholders at higher institutional levels.

Power relations and local ComMod practitioners

The legitimacy of the designers, and its facilitators and models in the ComMod process is often discussed among ComMod practitioners when dealing with multiple stakeholders with different levels of power in a community. The recognition of the underlying power dynamics and motivations for participation are precondition for a successful process (Prell et al., 2007). The role and management of power relations in a ComMod process is being debated among ComMod practitioners. A study by Barnaud et al. (2006) has specifically addressed the analysis of power relations in a ComMod process carried out in Mae Salaep village, Chiang Rai province, Northern Thailand. One main limitation of that ComMod implementation was the different way of thinking about the same problem between ComMod participants and non-participating villagers. The author suggested that before launching a ComMod project, more sensitizing activities about ComMod methodology and project objectives should be carried out with all stakeholders equally. The author also mentioned the need to find a local people and train them to become an autonomous and neutral facilitator, who can continue applying ComMod methodology and developing tools, in particular RPGs, in the village. This concern is especially acute once a ComMod process has been implemented. A qualified person (educational background, current job, etc.) is often not easy to recruit. Besides that, it takes time to train and develop a personal mental model about the ComMod approach and methodology to be able to apply it without inadvertently manipulating the process.

A ComMod experiment carried out in the Lam Dome Yai watershed, Ubon Ratchathani province, Thailand, definitely confronted these challenges mentioned above. However, a researcher who took several ComMod short training courses thought that ComMod is a promising approach to better understanding human-environment interactions in this watershed. The ComMod process of the Lam Dome Yai case is presented in the next chapter.

CHAPTER 8
THE FOUR SEQUENCES OF THE COMPANION MODELLING PROCESS IMPLEMENTED IN THE LAM DOME YAI WATERSHED

The research team was inspired by an initial discussion with villagers during a field survey in the Lam Dome Yai watershed conducted in the dry season of 2000, and by attending several short training courses on Multi-agent systems, computer science and INRM in 2002-2003. In the study area, labour shortage is an important limitation to farming as many working-aged people migrate to other regions to seek more profitable employment, leaving only children and elders in the village. Based on those initial discussions with villagers, the research team decided to analyze the problem of labour shortage in relation to land and water use because 80% of the land is dominated by agricultural uses, requiring a relatively high number of labourers. Fundamentally, the ComMod process was implemented at this study site because of the researchers' poor understanding of interactions between land/water use and labour migration that could lead to the failure of state-funded development of water infrastructures in the Lam Dome Yai Watershed.

From the researchers' point of view, the main objective of the ComMod activities was to better understand the interactions between land/water use and labour migrations across diverse farm types. The results of this research could then guide the design and adaptation of local water resource development projects in the future at a time when government authorities are planning ambitious and costly projects in this field. In this ComMod process, RPGs and ABMs have been the main modelling tools used with the various stakeholders to create a shared representation of the system via a platform of knowledge sharing and collective learning process used to co-design integrative models with local rice farmers. Such a shared representation promotes the importance of stakeholders agreeing on the functioning of the system under study and thus being able to be in a position to efficiently explore possible future scenarios of their choice. At the same time, stakeholders' adaptive management capacity can also be improved through this modelling process.

Following a preliminary diagnostic-analysis on the local agrarian system—comprising a review of the existing literature and a farm survey to fill knowledge gaps—carried out in 2004, an initial conceptual model was formalized in early 2005 and used to design a first RPG. The first participatory modelling workshop using this RPG was organized in July 2005 and was the entry point of the four successive sequences of that ComMod process. In this chapter, the selection of the study site and the participants are first presented. Then, detailed information on the process design and implementation is provided, before a final section that recapitulates the evolution of the modelling tools over the whole three year process.

8.1. Selection of Study Site and Participants in Lam Dome Yai Watershed

Ban Mak Mai village is located in the north of the Lam Dome Yai watershed. This village was selected for a series of participatory workshops because it is representative of the dominating RLR ecosystem of lower northeast Thailand. Participants were farmers living in this village, representing diverse farm types. Based on the farmer typology (See chapter 5), these participants were selected to cover all existing farm types found in this SAES. A total of 11 farming households (husband and wife) were invited to participate in this ComMod process. Eight small holders belonged to farm type A, two households represented type B, and one was a type C farmer (Table 8.1).

Table 8.1 Characteristics of the farming households from Ban Mak Mai village who participated in the ComMod process.

Household number	*Farm type*	*Area planted to rice (ha)*		*Farm pond (m^3)*	*Annual gross income (euros)*	*Social Network*	*Number of family members*	
		KDML105	*RD6*				*Workers*	*Dependents*
1	A1	0.8	0.8	0	400	No	3	3
2	A1	0.96	1.6	300	510	Yes	5	1
3	A1	1.6	0.8	144	860	No	2	2
4	A2	1.6	1.6	500	970	Yes	3	1
5	A2	0	1.6	158	570	Yes	6	0
6	A3	3.2	1.6	240	1,550	Yes	6	2
7	A3	2.4	1.6	450	1,300	Yes	5	3
8	A3	1.6	1.6	1,350	850	Yes	2	4
9	B1	7.04	1.92	2,400	2,200	Yes	2	4
10	B2	4.8	1.92	2,200	2,500	No	5	0
11	C2	6.4	2.4	3,840	2,900	Yes	5	1

A wealthy large land owner belonging to sub-type C1 was also invited, but she did not join in the activities because this ComMod process was initiated during the rice transplanting period when she was too busy in her paddies. The same reason also limited the number of participating type B farmers and sub-type C1, who had labour shortage problems. On the other hand, due to less labour constraints, more type A farmers could join the process. This selection also represented the majority and minority groups of farmers existing in the village.

8.2. Process Design and Implementation

A farm survey was conducted in 2004 to characterize the different main types of household-based agricultural production systems and the determinants of labour migrations among these different categories of farming households. The data showed that the farmers' decision-making regarding land and labour management was similar among the farmers belonging to the same type (similar livelihood objectives, farming strategies and means of production). These decision-making processes were essential to conceptualize the operational rules in the ComMod models. In early 2005, an initial conceptual model was formalized by using the diagrammatic UML.

A key feature of ComMod processes is the iterative alternating between field and laboratory activities. After each field workshop, field investigations were carried out, to acquire additional information (including a new farm survey in 2005 during the prolonged drought of the 2004-2005 crop year), as well as monitoring and evaluation activities to analyze the effects of the ComMod activities on participating farmers as well as to keep in touch with them (Figure 8.1). For more details about monitoring and evaluation activities carried out in this ComMod process, see Thongnoi (2009).

In this ComMod case study, throughout the cyclic process, different modelling tools, rooted in the same underlying conceptual model, were used with different complementary objectives. RPG and ABM used in association support each other in the system analysis and gradual improvement of the common underlying conceptual model (d'Aquino, Barreteau et al., 2002). The initial conceptual model, with key interacting components and the sequential operations of key activities in this RLR ecosystem, was depicted in complementary UML Class, Sequence and Activity diagrams. The design and implementation of the RPGs and ABMs will be fully described in the following RPGs and Ban Mak Mai Agent-Based Model chapters respectively. The four sequences of ComMod activities implemented in this process are presented below.

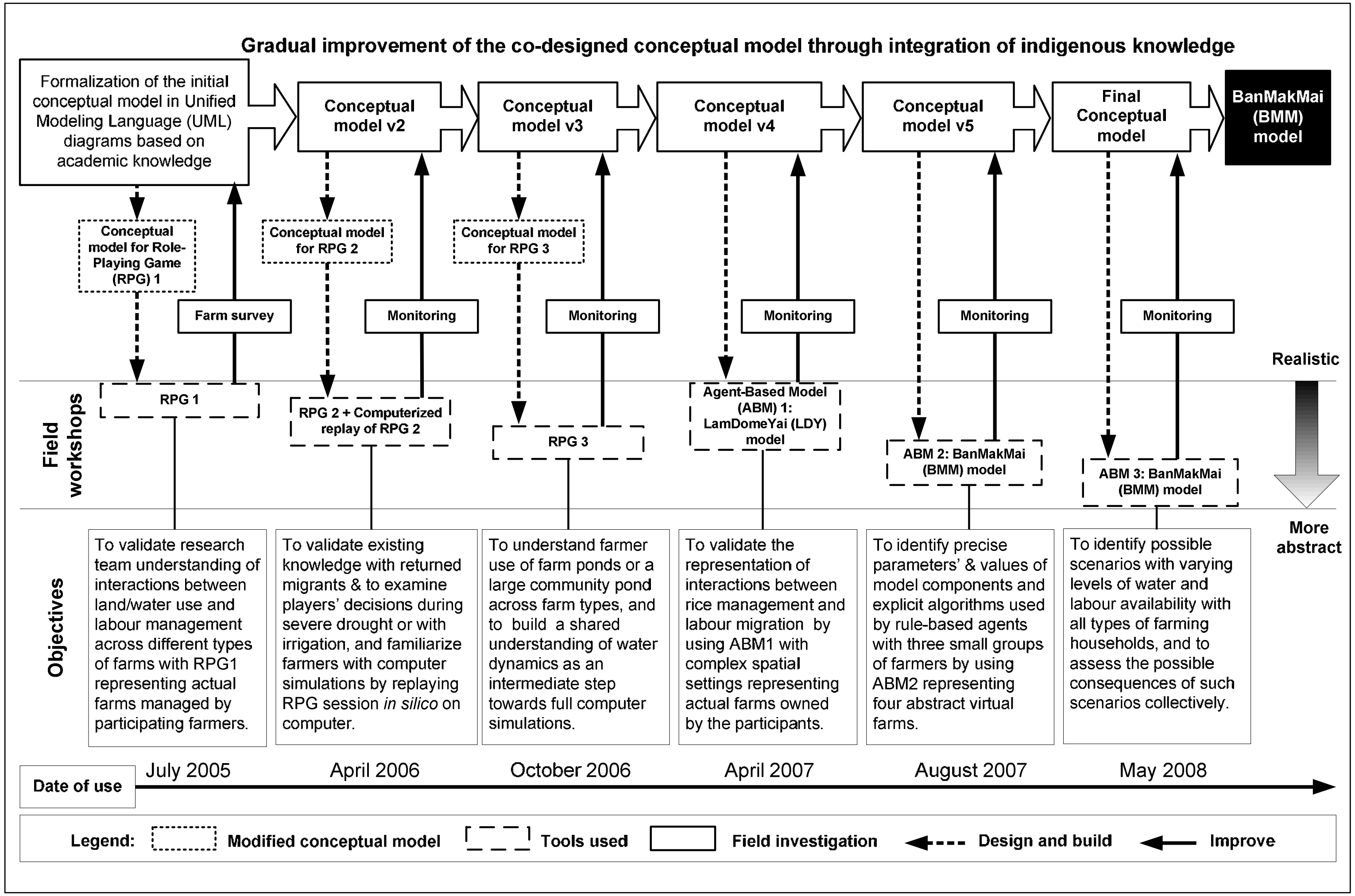


Figure 8.1 Description of the ComMod process implemented in the Lam Dome Yai watershed showing the evolution of co-constructed models, the specific objectives of successive workshops and the tools used 2005-2008.

8.2.1. First Sequence: Researchers' Knowledge Validation by Local Farmers

This sequence started once the UML diagrams were completed in early 2005 and ended in July 2005.

8.2.1.1. Objective

The aim of this sequence was to validate the research team's initial understanding of the interactions between land/water use and labour management across the farm types in the local RLR ecosystem. Another purpose was also to train a team of assistants to prepare and operate ComMod field activities.

8.2.1.2. Method and Tools

To be able to validate the research team's understanding of the system of interactions under study through local farmers' actions, the UML diagrams were simplified to implement a first RPG (Figure 8.1). This simplified UML omitted scientific hydrological processes, and depicted only RLR growing activities and labour migration practices. The yearly climatic cards were used to simply represent different rainfall conditions. This RPG was used with farmers in a first participatory modelling field workshop on 9-10 July, 2005. The research team used new information derived from local farmers' decision-making processes during the gaming session to enrich the initial conceptual model. The underlying theoretical assumption was that with the transparent structure and rules of the RPG made available to stakeholders, this tool would support the validation of the underlying conceptual model and its improvement through the acquisition of new knowledge on the system, while facilitating exchanges and collective learning among stakeholders.

The two-day workshop was made up of two main sessions (Box 8.1), starting with a gaming session in the first day. The gaming sequence was based on the main rice-growing phases: nursery establishment, transplanting, harvesting, and the post-harvesting period, including labour migration. Yearly climatic conditions (wet, dry, and very dry years) were drawn by a player. The players' decisions were driven by rice-growing phases associated with specific rainfall conditions, and their related actions were displayed on a 2D game board (Figure 8.2).

Box 8.1 The first participatory modelling workshop and its artefacts.

The first participatory modelling workshop using RPG1

Date: 9-10 July 2005

Meeting place: Ban Mak Mai School.

Participants:
Seven researchers, one NGO representative, one extension worker, seven research assistants and eighteen local farmers from eleven households; eight households came in pairs (husband and wife), and three households were represented by only one member.

Objectives:
To validate the research team's understanding of land / water use and labour management on the different types of farms, and to train and engage villagers in the action research process. Moreover, to initiate a collective learning process on land, water and labour management.

Main issue:
Focus on rice-growing steps and labour management as influenced by internal factors such as age, education, and household income, and by rainfall variability.

Gaming sessions:
(1) First day: the research team leader introduced the project in the first session. Then the RPG session started, moving through rice-growing phases that affect the players' decision making regarding land, water and labour use. The main phases in the game focussed on key rice growing stages: nurseries, crop establishment by transplanting, harvesting, and the post-harvesting period, including dry season activities. Four rounds were played to simulate four crop years over five hours. The players had different roles: farmers, migrants, and hired labourers.
(2) Second day: ninety minutes were spent on individual interviews of players, followed by two hours of plenary discussion with the participants to discuss the results of the previous day's gaming session and possible next steps.

Equipment and materials:
Thailand map; tokens; fake money, role cards; dice; computer software (Excel package); flipchart; post-it notes; camera; video camera and recorder.

Artefacts:
Game boards; game cards; writing pads to record players decisions.

Figure 8.2 First participatory modelling workshop based on a role-playing game in Ban Mak Mai village on 9-10 July 2005, **Top left:** players allocating rice-growing areas; **Top right:** players located where their migrant workers were working on a map of Thailand. **Bottom left:** a player selling his rice at the 'market'; **Bottom right**: plenary discussion after the gaming session.

Four rounds, equivalent to four successive crop years, were played. On the second day, a plenary discussion and individual interviews were held to compare what happened in the gaming session with actual circumstances, and to clarify the players' actions during the gaming session. In addition, the interviews were used to identify concrete water, land and labour management strategies actually employed on the farm. The findings of follow-up individual interviews were used to enrich the initial conceptual model and to design and build an improved second RPG. The players were divided into two groups during the individual interviews. Each group consisted of six players and one researcher. One research assistant interviewed a member of each household with the help of a semi-structured guideline document.

8.2.1.3. Main Results

The first field workshop held in Ban Mak Mai village demonstrated the feasibility of using such key ComMod collaborative modelling and simulation activities with 21 local farmers and two development officers. The research team (the process designer and his seven assistants) gained precious experience on how to facilitate such events to be used in the following sequences. The research team's understanding of the interaction between land & water use and labour management & migrations was validated, and our initial conceptual model was enriched,particularly, decision-making to hire extra farm workers and changes of migratory patterns across farm types when encountering different rainfall conditions. Differences in means of production available, especially farm size and family size and composition, played a crucial role in determining the availability of hired labour in the gaming session. The introduction of very dry annual conditions pushed farmers to migrate because inadequate water availability for farming caused unemployment. The risk linked to unpredictable wage levels introduced in the game, through the drawing of a "received wage" chance card when a player decided to migrate, did not influence the players' migration decisions.

Diverse farming households played different roles in the local labour market since different farm types have different cropping calendars and farm sizes, resulting in different labour needs. These differences also make some farmers, in particular less farm size farmers being available for hiring. When players hired labour, it was found that they based their decisions in the game on their actual practices. Due to their small farm sizes, type A farmers generally spent a shorter time completing rice-growing activities and were then hired in this game by larger farmers during the high peak labour demand periods of transplanting and harvest. In simulated drought years, farmers who produced rice only (small farm type A) tended to provide more out-migrants.

Although the spatial setting of the gaming board was rather abstract (Figure 8.2) and the rules quite simple, farmers considered that the game provided situations similar to their reality. A friendly relationship between the research team and the other participants was also reinforced throughout this highly interactive activity. The participants realized that a RPG was not only for kids but could also be useful for knowledge sharing, in particular when unpredictable rainfall conditions and wage levels were introduced in the game.

Meanwhile, the participating farmers underlined that returned migrants should also be able to participate in such gaming workshops because they wanted to share their perceptions of the issue at stake with these migrant workers. Therefore, they suggested holding another similar workshop just after mid-April when the migrants return home to celebrate the Thai New Year.

8.2.2. Second Sequence: Elicitation of Farmers' Decision-making Processes Regarding Migration in Relation to Water Availability

The second sequence was implemented similarly to the previous one. A revision of the conceptual model was produced to integrate the findings during the first participatory modelling workshop, and the second farm survey carried out at the beginning of this sequence.

8.2.2.1. Objective

This second ComMod sequence aimed at validating existing knowledge with participating migrant workers. Another objective was to observe and investigate changes in the players' farm and labour management decisions under different rainfall conditions, in particular prolonged drought and newly introduced irrigation canal scenarios.

8.2.2.2. Methods and Tools

Three methods were implemented in this second sequence. A specific farm survey was carried out in August 2005 after the exceptionally long drought of the 2004-2005 crop year. This survey aimed to understand farmers' decisions regarding the impact of drought on farm management including labour migration practices in order to integrate these decision-making processes into the initial conceptual model.

A second improved RPG, designed according to the revised conceptual model, was implemented in early 2006 and used with farmers just after the Thai New Year, at the end of the dry season when many migrants visited the village. The organization of this participatory modelling workshop was similar to the previous one (Box 8.2). The first day was devoted to an RPG session with features, rules, and materials similar to the first RPG. But in this workshop, the impact of water availability (scarcity or abundance) on farmers' decisions was particularly examined through the creation of two successive drought years and the introduction of an irrigation canal in the game. Six rounds (corresponding to six simulated crop years) were played. In addition, this time a computer simulator was introduced to replay the gaming session *in silico* in front of the players on the second day to facilitate exchanges and discussions about their actions in a plenary session (Figure 8.3).

Follow-up individual interviews were conducted by four research assistants at the end of the field workshop, and more interviews were conducted by RPG designers one month after the workshop. The follow up interviews aimed at gaining a more in-depth understanding of farm and labour management decisions made under the prolonged drought and abundant water scenarios simulated during the gaming session, and to compare those decisions to reality.

8.2.2.3. Main Results

The players' decisions to deal with prolonged drought were not different from what was observed during a very dry year in the first RPG session. Under the irrigation canal scenario, type A small land holders were more adaptive in take advantage of better access to water. They planted more cash crops in the dry season and there were fewer migrants on their farms. The returned migrant players did not participate in the first RPG, but their decisions on on-farm and off-farm employment for their household labour were not different from those of the participants in the first RPG session. The fact that the decision regarding labour migration is a collective agreement among household members was confirmed.

Box 8.2 The second participatory modelling workshop and its artefacts.

The second participatory modelling workshop using RPG2 and a computer model

Date: 20-21 April 2006.

Meeting place: Ban Mak Mai School.

Participants:
19 people, only one of them being a returned migrant, from 11 farming households. Nine households were represented by pairs and two sent a single member. Seven people were members of the research team. One extension worker and four research assistants participated in the workshop.

Objectives:
(1) To validate existing knowledge with the new migrant player, a member of a family who had participated in the first gaming sessions;
(2) To investigate the players' decision-making processes regarding farm and labour management under prolonged drought and irrigation canal scenarios;
(3) To train the research team in the action research process;
(4) To introduce replays of the gaming session by the computer as a collective learning support tool and to validate the model.

Main issue:
Farm management with returned migrants, and under severe drought and irrigation canal scenarios.

Gaming sessions:
The gaming sessions were carried out over two days:
(1) On the first day, the RPG was used to simulate scenarios with and without irrigation canals, taking five hours to complete six rounds (crop years): four crop years under rainfed conditions and the last two crop years with an irrigation canal. During the gaming session, traditional songs (Mo Lum) were sung by female players to entertain the other players. The wage chance cards were removed after the morning session because of the lack of players' interest in them; this helped to speed the game up.
(2) The second day started with a three hour plenary discussion about the proceedings on the previous day's gaming session and the replayed computer simulation was projected on the screen to help local farmers understand what the ABM was doing and what was happening during the simulation. Later on, individual interviews with 11 households were conducted by four research assistants.

Equipment and materials:
Thailand map; tokens; fake money, role cards; dice; computer software (Excel package); flipchart; post-it notes; camera; video camera and recorder.

Artefacts:
A game board and Excel package were used with the same objectives than in the first sequence.

Figure 8.3 Second participatory modelling workshop based on a role-playing game and computer simulation replaying the gaming session on 20-21 April 2006, **Left:** players receiving income from migrant workers. **Right:** plenary discussion about the players' actions in the gaming session, with a projected replay of the computer simulation.

This second RPG also helped the farmers to understand the rules and sequence of operations of a computer simulation thanks to the replaying of the gaming session. This helped them to better understand their own situation compared to others, and to examine the causes of actions made by other players. All the participants were eager to share their knowledge during the replay session. Linking the RPG session to this computerized replay helped participants become familiar with a computer simulation.

The irrigation canal scenario was useful in stimulating the player's thinking about what additional farm goods should be produced after rice production, but this kind of infrastructure is not readily available in reality due to the high investment required. According to the players' comments, a common pool resource, such as ponds, should be added as a new feature in the next workshop. Farmers' representation of water dynamics in relation to rainfall conditions was still needed to validate the hydrological processes and irrigation function in the model. This specific topic was taken into account when designing the third RPG that was to be used in the next ComMod sequence.

8.2.3. Third Sequence: a Shared Representation of Water Dynamics Interacting with Labour and RLR Management

This longest sequence was implemented between May 2006 and March 2008 and its key events were three participatory workshops held in the village.

8.2.3.1. Objective

The activities aimed to gain a more in-depth understanding of the players' decisions regarding the management of individual farm and community ponds, in relation to labour and RLR management. The RPG used in this sequence was designed to provide the participating farmers with further initiation in the use of learning through simulations of scenarios before the introduction of fully computerised simulations.

8.2.3.2. Methods and Tools

The third RPG

Box 8.3 describes the third field workshop held in Ban Mak Mai village on 10-11 October 2006. During the first day, participants played an RPG designed to acquire their perceptions about water dynamics in paddies and individual farm ponds in relation to weekly rainfall conditions. The weekly rainfall conditions were announced, and their related pictograms were pasted on a public calendar bulletin. Then, the players were asked to draw the water levels of paddies and ponds on decision sheets prepared by the game designer. On the second day, simple graphs and tables comparing the players' decisions during the first day's gaming session were presented and collectively analysed. Similar patterns within the rice-growing calendar and dates of water pumping from individual farm ponds were grouped and discussed to verify if the successive water levels indicated by the players in the gaming session were correct.

To create a singular situation, all participants also had to build a shared perception of water levels when using water from a community pond. Because only one assistant participated in this workshop, a short questionnaire was used instead of individual interviews. The objective was to check participants' understanding of the features and dynamics of the gaming session and the differences from the two previous workshops was distributed to all players. The plenary discussion was carried out after the gaming session to collectively define water availability of the community pond in relation to weekly rainfall conditions used in the game. The collective agreement derived from this plenary discussion was used to validate the water level in the ABM. Figure 8.4 shows the activities and materials used in the gaming session.

Even if the water use practices were better understood across the farm types, the water level of individual farm ponds and paddies was still difficult to be assessed quantitatively to sufficiently validate the hydrological processes of the ABM. This ABM integrated the water module of a previous ABM built to represent the hydrological processes in this RLR ecosystem (Lacombe and Naivinit, 2005). It became necessary to present it to the players for them to validate the water dynamics of ponds and paddies. Therefore, I decided to introduce this first ABM, named "LamDomeYai (LDY) model" after the local river, to the participating farmers in the following ComMod activities.

Participatory simulation workshop using the Lam Dome Yai (LDY) ABM

The LDY model was implemented to validate the knowledge and representation of interactions between water dynamics and labour migration through the use of computer simulations. Three major steps in the LDY simulations were rice establishment, rice harvest and dry-season activities (Box 8.4). To learn how the simulation worked, the participants were guided from looking at simpler (model configuration with two virtual farms only) to more complex (model configuration with eleven virtual farms) simulations.

The two virtual farms were introduced in the morning session on 24 April 2007. The hydrological module with homogeneous rule-based agents was presented to validate the representation of water dynamics in relation with RLR production practices. Two different paddy fields were displayed, with or without access to a pond. Players were 'rice-growing consultants' who delivered comments and suggestions to moderators acting as inexperienced rice farmers. After looking at the weekly rainfall conditions, the participants were asked to guess the outputs of simulated water levels in the paddy fields and the farm pond. This was the chosen way to validate this water module of the ABM with local 'RLR experts'.

Box 8.3 The third participatory modelling workshop and its artefacts.

The third participatory modelling workshop using RPG 3

Date: 10-11 October 2006.

Meeting place: Community building in Ban Mak Mai Moo 17.

Participants:
21 local residents participated; three of them were new participants from three households. Nine research team members were involved in the implementation of the activities.

Objectives:
(1) To acquire knowledge on players' water use and labour migration strategy across farm types when encountering different water availability;
(2) To improve agents' water-use rules in the LDY model;
(3) To provide the players with a supporting tool for learning about simulations and scenarios through a new RPG before introducing an ABM simulation.

Main issue:
Agreement on a common representation of water dynamics.

Gaming sessions:
(1) First day: three key phases of the rice growing cycle (crop establishment, harvest and dry season activities) were built into the game. Rainfall pictograms were used by the facilitator to visualize the amount of rainfall on a weekly basis. Players were assigned to produce rice under two predefined scenarios with individual small ponds or a larger community one. Six rounds of play were implemented for each of them;
(2) Second day: simple illustrations to compare the decisions among players were prepared and presented to them for participatory analysis. Similar patterns within the rice-growing calendar and dates of water pumping in individual farm ponds were grouped and presented to the players for collective discussion. A short questionnaire on their understanding of the features, contents of the game, and its differences with the ones used in the two previous workshops was given to all players.

Equipment and materials:
Post-it notes; camera; video camera and recorder.

Artefacts:
Players' decision sheets to record their decisions, weekly rainfall condition bulletin board, pond and paddy field water level boards.

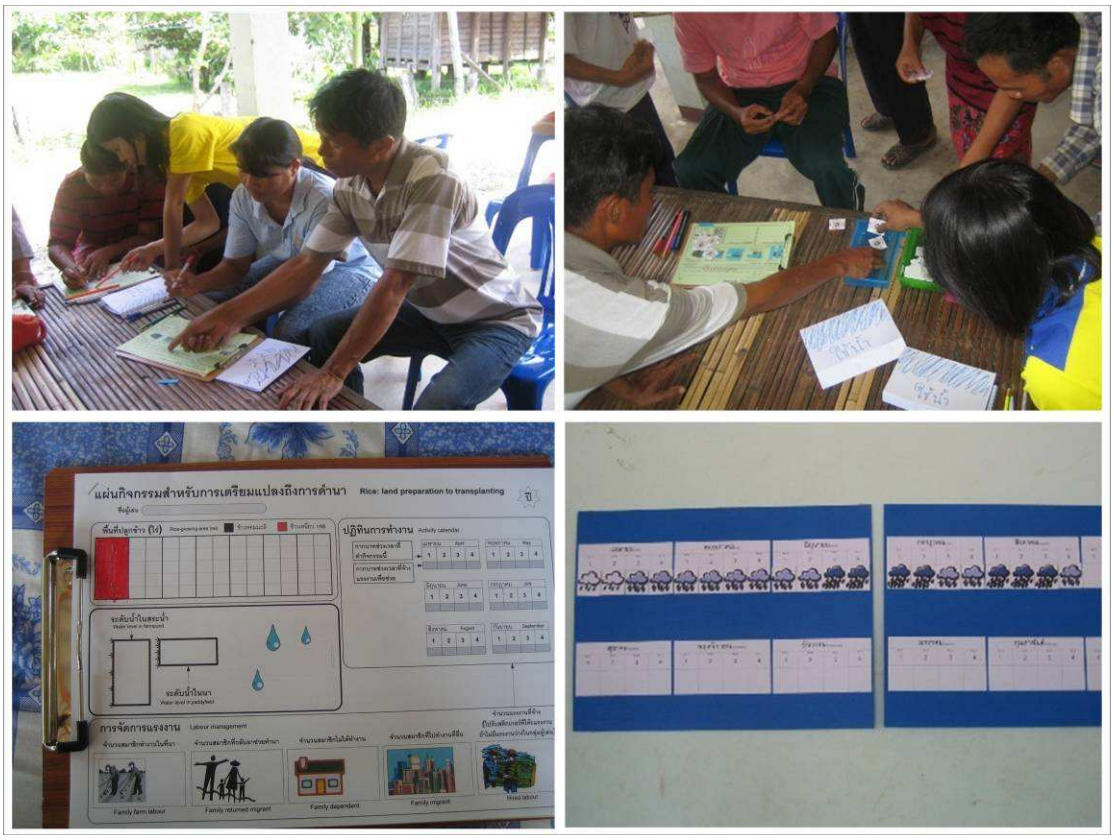


Figure 8.4 Third participatory modelling workshop based on a role-playing game in Ban Mak Mai village on 10-11 October 2006, **Top left:** a couple discussing before drawing the water level in their paddies and pond on the decision sheet; **Top right:** players deciding the amount of rice produced before pasting bag pictograms on their decision-sheet. **Bottom left:** decision sheets completed by a couple of players from the same household; **Bottom right**: pictograms on a public bulletin board showing the weekly rainfall conditions during the rice crop cycle.

This simple setting was also used to refresh participants' memories of the LDY co-designed activities implemented during the previous workshop in October 2006. In the afternoon session, a more complex simulation with eleven virtual farms representing the actual holdings belonging to participants was introduced (Figure 8.5). The simulation displaying heterogeneous groups of rule-based agents representing diverse farm types was run to validate the interaction between water dynamics and labour migration with these expert farmers.

Box 8.4 The participatory simulation workshop using the LDY model.

Participatory simulation workshop using the LDY model

Date: 24 April 2007.

Meeting place: Community building of Ban Mak Mai Moo 17.

Participants:
21 local residents; three of them were new participants from three households. Nine research team members were involved in the implementation of the activities.

Objectives:
(1) To validate the understanding of interactions between on-farm or community pond use and labour management;
(2) To calibrate the hydrological module of the LdyModel, representing the water dynamics according to rainfall and players' decisions;
(3) To discuss the on-farm and community pond scenarios with the players, and to define other future ***scenarios*** to be explored by using ABM simulations.

Main issue:
Community and on-farm pond water use and interactions with labour management.

Simulation sessions:
Three major steps of the LDY model simulations were rice crop establishment, rice harvest and dry-season activities. The sessions were organized in two parts:
(1) An initial part introduced a simple scenario with only two different paddy fields: one with a pond and the other without. Players were acting like consultants, giving recommendations for rice transplanting to the moderator who acted as an inexperienced farmer;
(2) A more complex configuration showing eleven actual farms was introduced in the last gaming session. The moderator asked the participants questions concerning the decisions farmers made with regard to rice-growing practices and water pumping, household by household across all farm types.

Equipment and materials:
Camera; video camera and recorder.

Artefacts: Players' decision sheets to record their decisions, weekly rainfall condition bulletin board, pond and paddy field water level boards, and ABM simulation.

Figure 8.5 Participatory simulation workshop using LDY model on 24 April 2007, **Top left:** simple interface with two virtual farms and water levels in paddies and pond introduced in the morning session; **Top right:** local farmers looking at a LDY simulation. **Bottom left:** interface with eleven farms used in the afternoon session; **Bottom right**: exchanges among participants during a simulation run.

It was found that the simple configuration with two virtual farms was more effective in stimulating collective exchanges and learning than the more complex one. I also had difficulty conducting model validation steps with highly heterogeneous participating farmers. Therefore, to enhance participants' communication, I decided to organize smaller participatory simulation meetings with homogeneous groups of farmers belonging to the same type of farm to improve the model calibration and validation.

Fine-tuning the Ban Mak Mai (BMM) model with small and homogeneous groups of farmers

The name of the ABM was changed from Lam Dome Yai (LDY) to Ban Mak Mai (BMM) to truly represent the decision-making processes of field collaborators, and to give them a higher sense of ownership of this new model representing the local rice farming conditions in Ban Mak Mai village. Three visits were made between August 2007 and March 2008 to refine the first version of the ABM, with three small homogeneous groups of farmers belonging to the same farm type participating.

Two different artefacts, a set of simple drawings and successive versions of the BMM model itself, were used. In August 2007, three group discussions on the model algorithms of rule-based agents were organized by using drawings (Figure 8.6). The underlying assumption was that while the ABM simulation was spatially explicit enough to display changes in land use as a result of interactions between the computer agents and their virtual environment, the algorithms used to operate the computer agents and their dynamics had to be made explicit by using simple drawings. Furthermore, this was also a preparation stage for participants before exposing them to fully computerised BMM simulations.

The proceedings included: (i) the presentation of algorithms that were built in UML diagrams and later used to implement the ABM. They were translated into simple drawings projected on transparencies and dealt with algorithms of agents' decisions during RLR crop establishment, RLR harvest and post-harvest period; (ii) the participants were divided into three small groups: two groups of four type A householders (eight people) and three households (six people) of farm types B and C in the last group.

Among the two scenarios used, the first one was based on the current actual situations faced by farmers; one situation offered the use of a pond, while the other situation did not. The second scenario simulated severe drought conditions, and 'what if' questions were asked to stimulate the participants to think beyond their actual circumstances. This second scenario also aimed at identifying other 'what if' situations that would lead to new relevant scenarios to be simulated with the players. The workshop was implemented at the house of a TAO representative for this village on August 5, 6 and 10, 2007. The meeting place for the workshop needed to be quieter and darker than previous locations. Among the 21 local farmers who participated this time, one was a returned migrant and another one was an observer. Two researchers and one research assistant were also present.

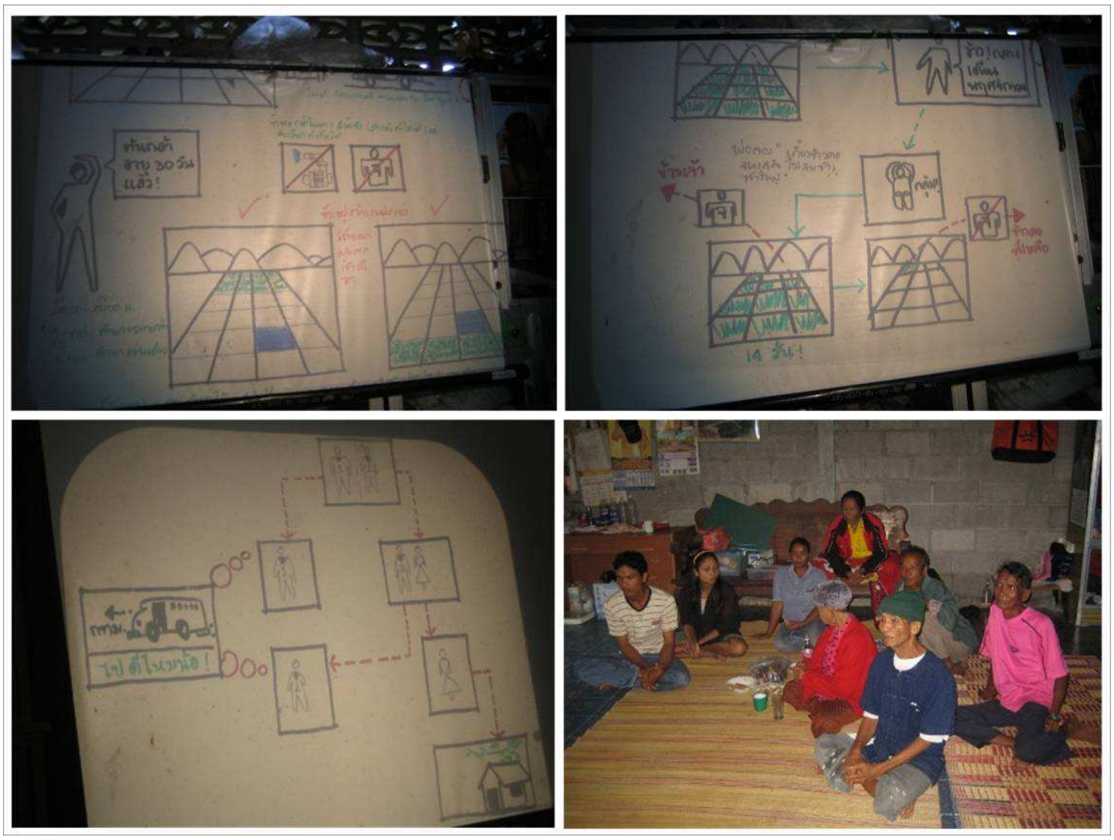


Figure 8.6 Participatory modelling workshop using drawings on 5-6 and 10 August 2007, **Top left:** a drawing showing initial location of transplanting activity and indicating no water use for this practice; **Top right:** a drawing to discuss the hiring of additional farm workers to harvest rice. **Bottom left:** a drawing to discuss migration practices; **Bottom right:** small groups of participating type A farmers.

Similar sessions were implemented a second time, at the same place, on 5-6 February, 2008. A smaller group of participants was invited, based on their capacity to follow simulations and their degree of involvement in the discussions during the previous workshop. This time, the BMM model was directly used with participants without more explanations given on drawings (Figure 8.7). The aim was to validate the model with a focus on identifying precise values of several key parameters and variables, as well as useful indicators to be observed during simulations and to be included in the BMM model. During the run of the BMM model, the moderators operated the simulation slowly to allow the participants to observe, discuss and propose changes in the dynamics visualized on the screen. The decision process on hiring labour during RLR transplanting and harvest periods could not be successfully validated because of the lack of diverse farm types in the room. Larger farms (type B and C) often hire additional farm workers from small farming households (type A) during RLR transplanting and harvest periods. Therefore, a last field work of this sequence focusing on this topic was organized in March 2008 with four selected households covering the three main farm types.

Figure 8.7 Participatory simulation workshop using the BMM model on 5-6 February and 19 March 2008, **Top left:** moderator operating the simulations; **Top right:** interface of the BMM model showing four different farms. **Bottom left**: a participant describing the features displayed on the BMM interface; **Bottom right:** a small group of participating type B and C farmers.

8.2.3.3. Main Results

Results from the third RPG session

For very small land holders, water is conserved to be used in cases of long dry spells that affect rice seedlings' growth, while other farm types also use water to establish nurseries. However, this decision is also dependent on the location of the farmer's paddy fields. Farmers who grow rice on lower paddies, where water is naturally adequate, usually use water to establish nurseries no matter how large their paddy fields are. In the gaming session, the difference in water use between wet and very dry years was in the frequency of water pumping. In the community pond scenario, improvement in water availability effectively provoked an increase in farm intensification on very small holdings but not for other farm types facing labour constraints. As a result, the number of migrants from very small holdings decreased when water availability was improved, while the number of migrants from the other two types of farms did not change.

The display of weekly rainfall conditions provided more precise information to the participants who felt more confident when deciding what water-related activities in RLR production practices should be undertaken. From the participants' point of view, the pumping of water from ponds for RLR production introduced in this game made it closer to reality. The collective pond was effective in stimulating knowledge sharing. Different water use strategies, depending on water availability, across the farm types lead to different cropping calendars for rice crop establishment and regulation of the availability of hired labour during RLR transplanting in this village.

Results of participatory simulations using the LDY model

The LDY model allowed the moderator to introduce virtual farms, and all participants were able to collectively criticize the actions of rule-based agents and suggest modifications. Since the LDY model was constructed based on the same conceptual model than the previous RPG, the participants had no difficulty in understanding its structure and operating rules. The two virtual farm versions successfully encouraged communication among participants. Water levels in the paddies and pond were displayed on screen on a weekly basis and used for rice-growing activities. Participating ‘experts’ helped the moderators, who were acting as inexperienced rice farmers, handle the changing situation. As a result, I quantified these water level changes and used that data to verify and calibrate the hydrological processes represented in the LDY model.

The version that simulated eleven realistic farms did not stimulate a collective discussion about the interactions between water dynamics and labour migrations; instead, the participants focused on correcting what they perceived as ‘mistakes’ made by the model displayed on the screen, rather than sharing opinions on the proposed representation of the interactions between water dynamics and migratory behaviours, and discussing desirable scenarios to be examined later. As a result, these interactions were not sufficiently validated at this stage and no scenarios to be explored were identified. The lessons learned from this experiment helped the researchers think about better spatial settings to stimulate knowledge sharing and learning.

Results from participatory simulation to fine-tune the BMM model

Drawings of the rule-based algorithms helped participants to get a clear picture of the cause-effect relationship of the actions operated by agents. Several parameter values were precisely identified during the BMM model fine-tuning activity (See details of this model in the description of the Ban Mak Mai model chapter below). At the end of this ComMod sequence, the BMM model was validated by small groups of participating farmers, but it was not yet used to identify interesting future scenarios to be simulated and assessed collectively. However, the players better understood the principles of ABM simulations and this enabled the research team to use simulated scenarios exploring ‘what-if’ conditions. Based on these results and to achieve the objective of knowledge discovery, the fined-tuned BMM model was selected as the key artefact to be used in the final sequence of this ComMod process.

8.2.4. Fourth Sequence: The Final BMM Model and Its Use with Local Farmers

8.2.4.1. Objective

This last sequence of the ComMod process used participatory ABM simulations to validate the BMM model with all participants, and to identify and explore scenarios of interest proposed by local farmers.

8.2.4.2. Method and Tools

A last participatory simulation field workshop was organized on 13-14 May 2008 and was made up of two sessions (Box 8.5). The first session aimed to validate the model and identify possible scenarios of interest with participating farmers, and the second one used simulations to explore these scenarios. The BMM model was improved based on the results of the previous ComMod sequences and was here used to facilitate discussion among participants (Figure 8.8). The spatial characteristics of the baseline scenario represent land use types (paddies, pond, and human settlements: house, village, city). Four farming households with different number of members in each household were rule-based agents. There were two small farms (3.3 ha) and two large ones (6.5 ha) with different pond sizes.

A ‘Household’ is made of heterogeneous ‘Member’ agents having different demographic characteristics (age, gender, and marital status). The ‘Household’ is a key decision-maker responsible for assigning specific roles (farmer, seasonal migrant, more permanent migrant or dependent) to its members. Once RLR is planted, it grows from seedling stage to maturity. Three main decision-making processes are: (i) decisions during nursery establishment and transplanting, (ii) decisions at harvest, and (iii) decisions after rice harvesting, including migration (See details on the BMM model description in Ban Mak Mai model chapter below).

Box 8.5 The final participatory simulation workshop using the BMM model.

Participatory simulation workshop using the BMM model

Date: 13 -14 May 2008.

Meeting place: Ban Mak Mai School.

Participants:
21 participants: 15 people from eight households and 6 members of the research team.

Objectives:
(1) To validate the final version of the BMM model and;
(2) To explore to scenarios with varying availability of water and hired labour.

Main issue:
The gradually co-constructed BMM model to be validated by local expert farmers.

BanMakMai model: The BMM model included:
(1) A spatial configuration consisting of two small farms (21 rai or 3.36 ha) called farm A and B, and two large farms (41 rai or 6.56 ha) called farm C and D, and different farm pond sizes;
(2) Farm A had 3 labourers and 3 dependents, farm B had 4 labourers and 2 dependents, farm C had 2 labourers and 1 dependent, and farm D had 3 labourers and 4 dependents;
(3) Different rainfall distribution patterns, whereby daily and weekly rainfall were fed into the simulation and displayed by explicit pictograms on the projected main interface.

Simulation sessions: The steps of the sessions were:
(1) Introductory VDO presentation about the previous workshops to refresh the players' memories;
(2) Running the BMM model slowly, step by step, and allowing the players to identify all its features and sequential operations in the simulation to discuss them and to propose possible scenarios to be simulated (for example: 4 farms with no individual ponds and 4 farms with individual ponds, hiring labour among the represented farms, and hiring labour from outside the village);
(3) A final plenary discussion about the scenarios to be simulated proposed by participating farmers.

Equipment and materials:
Camera; video camera and recorder.

Artefact: the BMM model**.**

8.2.4.3. Main Results

The BMM model running the baseline scenario was validated by the local farmers who accepted that this model sufficiently represented the system under study. Participating farmers used the BMM model to identify interesting scenarios to be simulated. They were interested in examining the effects of: (i) a recent increase in the number of cheap foreign labourers from Lao PDR and Cambodia who can be hired during RLR transplanting and harvest periods, and (ii) adequate water availability, thanks for instance to an irrigation canal, on the system dynamics. The simulations were used to explore the consequences of the interactions between the model components on the emerging behaviour of the simulated system under the specific conditions (see details in chapter 9).

Figure 8.8 Participatory simulation workshop using the BMM model in Ban Mak Mai village on 13-14 May 2008, **Left:** moderator operating the simulations and discussing with participants. **Right:** the main interface of the BMM model growing four rice farms.

8.2.4.4. BMM Model Presentations to Scientists by Local Farmers

The BMM model constructed with local farmers for knowledge sharing and discovery was put to use in two special meetings between local farmers and scientists. On 11 June 2008, four representatives of the participating farmers used the BMM model to exchange knowledge with a delegation of international scientists working for the PN 25’s ‘Companion modelling for resilient water management’ project of the CGIAR Challenge Program on Water and Food (CPWF). In addition, a special seminar was organized at the Faculty of Agriculture of Ubon Rajathanee University on 18 October 2008 to give nine of Ban Mak Mai collaborators the opportunity to present the BMM model in front of researchers and 70 master students studying in the Information Technology for Agricultural and Rural Development (ITAR) program (Figure 8.9).

Figure 8.9 Local farmers using the BMM model to exchange their knowledge with scientists and master students in two special meetings, **Top:** Four representatives of the participating farmers explaining the model features to visiting scientists by using the BMM model. **Bottom:** Nine representatives of participating farmers using the BMM model for discussions with lecturers and master students at the local university.

8.3. Recapitulation of the Evolution of the Co-constructed Model along the ComMod Process

Based on the typology of relationships between RPGs and computerized models proposed by Barreteau (2003a), in this case study, the three RPGs and two ABMs used in succession were based on the same underlying, gradually improved and shared conceptual model. In addition, the three different modes of gaming to support the co-construction of the ABMs were: (i) games used for mutual knowledge acquisition and model design, (ii) games used as a communication tool between a model and real circumstances, and (iii) games used as a medium to explain the contents of a computer model; in this case the game was a simplified version of the computer model. Even if RPGs were proved necessary to support the implementation of an ABM they have been time-consuming and costly. To overcome such RPG limitations, an ABM was introduced to participating farmers once I was confident that they were able to understand and follow computer simulations. Using an ABM enhanced collaborative support in design and analysis of the conceptual model because such ABM entails the repetition of rapid, prevents repetitive and time consuming RPG sessions, and provides results of simulated experiments for collective assessment (Barreteau, 2003a). The first prototype BMM model (the LDY model) was implemented and completely replaced the use of RPGs in April 2007. Since then, all the remaining co-designing activities were carried out by using BMM computer simulations.

The attempt to integrate a map of the study site into the spatial interface of the first ABM was found in the LDY-GIS model. This was proposed to represent the realistic spatial entity of the study site and develop it with local farmers. However, the map scale was too large to be used to observe changes at the micro level, which was reserach focus. Later, I downsized to look at farm level with a model representing the eleven actual participating farming households. Therefore, the model named "LDY-RPG model" was introduced to the participating farmers during the second participatory modelling workshop after the RPG session had been played (Table 8.2). During the gaming session, data regarding decisions made by participating farmers were recorded in the Excel spreadsheets. The simulation was only operated and displayed based on these data. Thus, this computer simulation can be considered as just a replay of the gaming session and not an autonomous ABM simulation. This replay by the computer was used to stimulate knowledge exchange and discussion of individual actions taken during the gaming session. This exercise was also a learning step toward helping participating farmers to relate the RPG to computer simulations.

The first prototype ABM (the LDY model) was used in the participatory simulation workshop organized in April 2007. The visualization was implemented to represent elevens farms resembling the actual farm sizes, farm components and farm locations (upper, middle and lower paddies) belonging to each participating household. Another modification was made to the timing: from a weekly basis used in the LDY-RPG model to a daily basis in the LDY ABM, thus corresponding to daily decisions made by local farmers.

As the complex and too realistic spatial configuration used in the LDY model did not provide good results, I decided to simplify it to represent only four virtual farms with differences in size, and water resources (Figure 8.9). These abstract landscape settings were designed to enhance discussion by shifting the participants' focus from sticking to their own actual situations to being 'experts' on the management of virtual RLR farms and providing comments on their agents' actions observed during simulations. However, the main principle of the landscape configuration in this simplified BMM model (toposequence and land use types) was not different from the complex one. The BMM model was finalized after the workshop on 13-14 May 2008 and was used for scenario identification and exploration with farmers, and in the laboratory. (See table 8.2 for characteristics of these two models).

Table 8.2 Characteristics of the family of agent-based models constructed during the ComMod process in the Lam Dome Yai case study.

Model name		LDY-GIS	LDY-RPG	LDY	BMM
Objective		To represent the whole study area based on field survey	To replay players' actions during gaming session for discussion in plenary session	To assist model validation through participatory simulations	To fine tune the validation of the ABM and explore scenarios
Source of spatial configuration		Study area (GIS map)	11 farms like the game board	11 farms & abstract spatial setting	4 farms & abstract spatial setting
Representation of diverse farms		Created randomly based on demography and farm types	11 households with their actual characteristics		4 archetypes of farm types A, B and C
Cell size		400x400m (16 ha = 100 rai)	20x20m (0.04 ha = 0.25 rai)		
Area displayed on interface (sq.km)		1680	1.92	1.44	0.45
Land use types		5 (paddies, other crops, forest, water, settlement)	3 (paddies, water bodies and human settlement)		
Hydrological features and processes	*Tank size (sq.m.)*	160,000	None	400	2,800- 9,600 (at random)
	Ponding tank proces	Infiltration - evapotranspiration - run-off	None	Infiltration - evapotranspiration - run-off	Plant-soil system water outflow & run-off
	Water storage tank	Evaporation & run-off	None	Evaporation & run-off	
	Root zone tank	Percolation	None	Percolation	None
	Subsoil tank	Discharge	None	Discharge	None
Time step (days)		1	7	1	
Strengths		Covers all main land use types with actual location in the study area.	Easy to understand as all settings are same than in the game.	Fully autonomous agents & representation of space, calendar, water levels similar than in the game.	Enough to represent the system and stimulate discussion to identify scenarios & to explore them.
Weaknesses		Cell size too large to represent land use at farm level. Slow simulations.	Cannot accomodate changes as data directly fed from the game to the simulator.	Participants focus on specific situation of their own farm displayed on screen and do not discuss the simulations.	Most abstract spatial settings with simple water balance assessment.
Use in simulation workshops (date)		No	20-21 April 2006	24 April 2007	13-14 May 2008

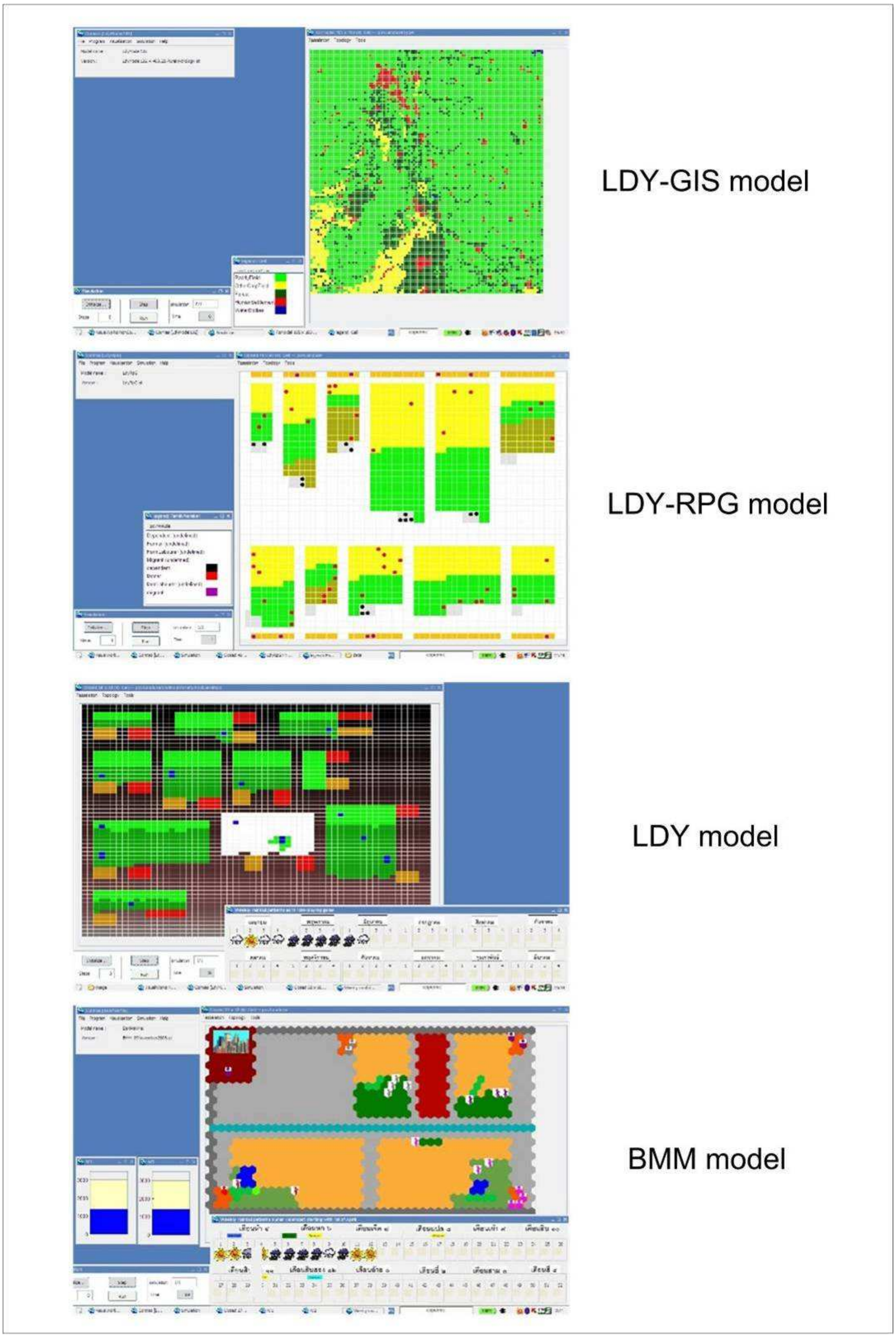


Figure 8.10 Evolution of the spatial configurations of the main interface of the successive computer models in the Lam Dome Yai case study: from singularity to abstraction.

Another major difference between the first ABM and the final BMM model was the adoption of a simpler hydrological module. The representation of complex hydrological processes related to the water balance in soil, such as evapotransipation, infiltration, percolation, and diffusion that were developed to precisely simulate the availability of water in paddy fields and ponds in an initial model were finally discarded. I took this decision to keep the BMM model as simple as possible. I also had difficulty in making these hydrological processes transparent to participating farmers in the co-designed modelling process. Moreover, during this long collaborative modelling process, it was found that farmers decide what action should be taken mainly by observing the daily rainfall conditions. As a result, this complex hydrological module was replaced by a unique parameter to remove 10 mm of water as daily outflow from a paddy field (See details in the description of the BMM model in chapter 10). However, I retained two virtual hydrological surface tanks (ponding tank in paddies and water storage tank in pond) to operate the run-off and evaporation processes. Another important outcome of this collaborative modelling experiment was the various types of effects generated by the ComMod activities on this sample of participating farmers and their social network. Their knowledge acquisition, and changes in perceptions, decision-making, behaviours, and actions, were monitored and evaluated under the ComMod monitoring and evaluation activities. The details of all results generated by this specific ComMod process are provided below in a specific chapter on the assessment of ComMod's effects.

PART 3 RESULTS

CHAPTER 9
THE THREE ROLE-PLAYING GAMES IMPLEMENTED IN LAM DOME YAI WATERSHED

Role-Playing Games (RPG) are an interactive tool to support knowledge sharing through simulated action and dialogue; that simulation might, in effect, influence action and practice in actual circumstances (Daniels and Walker, 1996). Participants assume certain roles and determine their actions based on their roles within the rules designed in a game. For the purposes of research, RPGs can be used to synthesize stakeholders' (as 'game players') perceptions when they interact freely with each other under a given set of assigned game conditions. Both the game organisers and players can learn from each other in such an interactive pattern (Hare, Heeb et al., 2002).

Games are certainly simpler than reality, but games can simulate some complexity, which is partly controlled and thus can be studied (Barreteau, 2003a). Simplified representations of complex systems emerging from a multiplicity of interactions between social and ecological processes are useful in that they can help us better understand complexity (Barreteau, Le Page et al., 2007). Within games, players behave as they do in reality. They make choices within contexts and in roles, bringing with them their own habits and strategies. The key goals of using RPGs in this study was to enhance interactions among players and to provide support for an ABM design and analysis leading to better understanding of the real world system.

The RPGs used for the purposes of this study can be defined as a kind of model representing a part of an RLR ecosystem, with a focus on interactions between land & water use and labour migration. During three RPG sessions implemented in this study, the relationship between the research team and participants was promoted through interactive knowledge sharing activities. With more transparent RPG structures and rules for the stakeholders, the RPGs were also a tool used to facilitate the knowledge exchange among players. At the same time, the initial conceptual model representing the system under study was enriched as a result of the knowledge generated from the RPG sessions leading to the improvement of an ABM.

In order to understand better the RPGs implemented in this study, a background to the Overviews-Design concepts-Details (ODD) protocol is provided below. Moreover, the Unified Modelling Language (UML) diagrams used to represent the conceptual model of the RPGs are also presented. Descriptions of the three successive RPG sessions implemented in this study are then provided.

9.1. Materials and Methods

9.1.1. Overviews-Design Concepts-Details (ODD) Protocol

The ODD protocol was developed by a group of modellers to be the standard format for describing an Individual-based Model (IBM). However, it is also possible to use this protocol to describe any bottom-up simulation model such as ABMs and RPGs (Grimm, Berger et al., 2006). Three blocks of elements within the protocol were defined: Overviews, Design concepts and Details.

The aim of the Overviews block is to provide sufficient information about the model to readers so that they would be able to re-implement the skeleton of the model. This block has three elements: (i) Purpose, (ii) State variables and scales, and (iii) Process overview and scheduling. First, the purpose of the model is to inform readers what is to be done with the model. The state variables and scales outline the structure of the model, specifying all types of entities and their low-level state variables[14] in the model. The spatial and temporal scales used in the model are also covered in the Overviews block. The process and scheduling section are described by listing all the processes that occur in the model and how they are scheduled (Polhill, Parker et al., 2008).

The Design concepts block deals with a wide range of high-level concepts related to the field of Complex Adaptive Systems (CAS) such as emergence, adaptation, fitness (objective), interaction, stochasticity, and observation etc.

The Details block aims to describe key entities, process and scheduling in detail so that the model can be completely re-produced. The Details block has three elements: (i) Initialization, (ii) Inputs, and (iii) Submodels. The initialization deals with how the environment and the individuals are created at the start of a simulation

[14] Low-level state variables cannot be deduced from other state variables because they are elementary properties of model entities. For example, individuals might be characterized by age, gender, location etc.

run. Environmental and economic conditions such as precipitation and product prices that influence all entities in the model are considered as "inputs". All submodels representing the processes listed above in "Process overview and scheduling" are presented and explained in detail. Additionally, as recommended by some ABM modelers (Le Page and Bommel, 2005; Richiardi, Leombruni et al., 2006), Unified Modelling Language (UML) diagrams are complementarily used with the ODD protocol.

9.1.2. Unified Modelling Language (UML) Diagrams

The UML is a family of graphical notations used in describing and designing object-oriented data modelling (Pukdeewatanakul and Komklom, 2005). Most UML tools are intended for an audience who will translate the UML diagrams into programming code, and most UML tools do not offer support for entering simple data to validate a data model (Schank and Hamel, 2004). The UML are classified into structural and dynamic diagrams.

Among structural diagrams, the static UML class diagram is always implemented to display the structure and relationship among components within a system (Fowler, 2004). The dynamic diagrams display the activities of objects in a system. It reveals the dynamic of the system. Two kinds of dynamic diagrams are often used for this purpose: activity and sequence diagrams. The activity diagram is used to model computations and workflows of an object. The sequence diagram is used to display an interaction, as a two-dimensional chart, between a vertical dimension showing time (the lifeline) and a horizontal dimension showing interacting objects (Rumbaugh et al., 1999).

UML class diagrams are used to show the structure of the model, thus completing the static representation in the Overviews of ODD protocol; UML sequence diagrams are used to elucidate the process overview and scheduling. In this case study, these diagrams were produced to represent the conceptual model to implement an ABM. As a result, the diagrams are too complicated to design a simple game. They were simplified to sufficiently cover the specific objectives of each RPG implementation.

9.2. Description of the Successive Role-Playing Games Used in This ComMod Experiment

9.2.1. The First RPG Session

9.2.1.1. Overviews

The purpose of the first RPG session was to validate the research team's understanding of land/water use and labour management on the different farm types, and to train assistants to prepare and run ComMod field workshops. This RPG was structured by four main groups of entities: spatial group (2D game board), operators (moderator, job broker and market manager), passive group (annual rainfall conditions and map of Thailand), and player as shown in the UML class diagram (Figure 9.1).

Low state variables were rice production cost (7,500 baht per ha) and daily labour cost. Daily labour cost for hired workers from other villages at transplanting was 250 baht per person, and 300 baht per person at harvesting, as indicated by Ban Mak Mai farmers. The five main steps of the game were designed to correspond with as many key stages of the rice-production cycle, as displayed in Figure 9.2. Four successive crop years were played. The gaming process and scheduling were driven by the change of events operated by the moderator as shown in the UML sequence diagram (Figure 9.3).

9.2.1.2. Design Concepts

The players' adaptation had to be observed when the very dry year card was drawn as the players may change the respective sizes of glutinous and non-glutinous rice areas. The lower rice yields and low incomes were designed in the very dry year, and thus more migrant workers were expected to generate more income and compensate the rice production losses through off-farm employment. The interaction among the players across households had also to be observed when the players looked for additional farm workers during transplanting and harvesting periods.

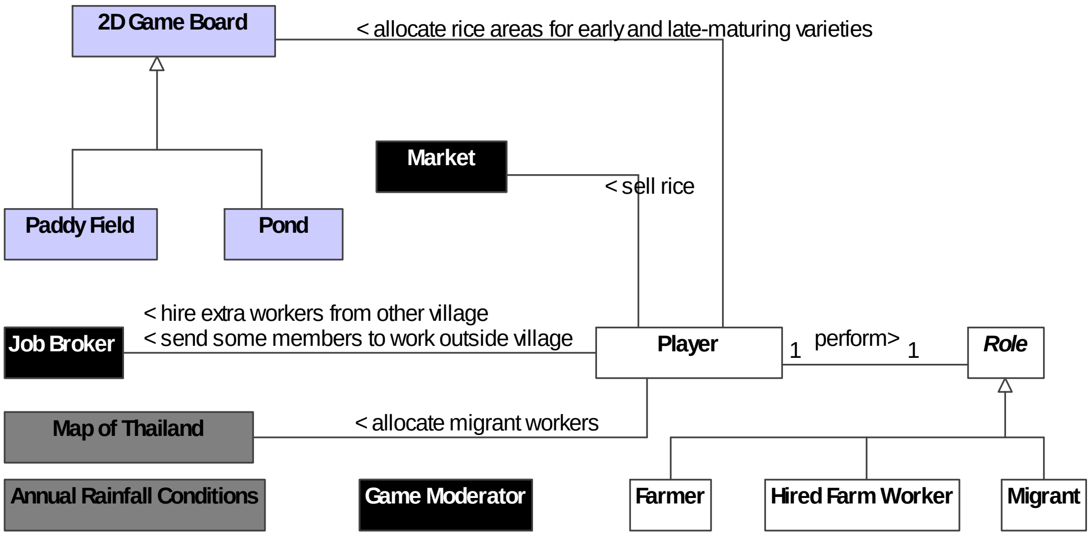


Figure 9.1 The first RPG conceptual model in a UML class diagram displaying key entities and their relationships.

Figure 9.2 The five successive steps in the first RPG.

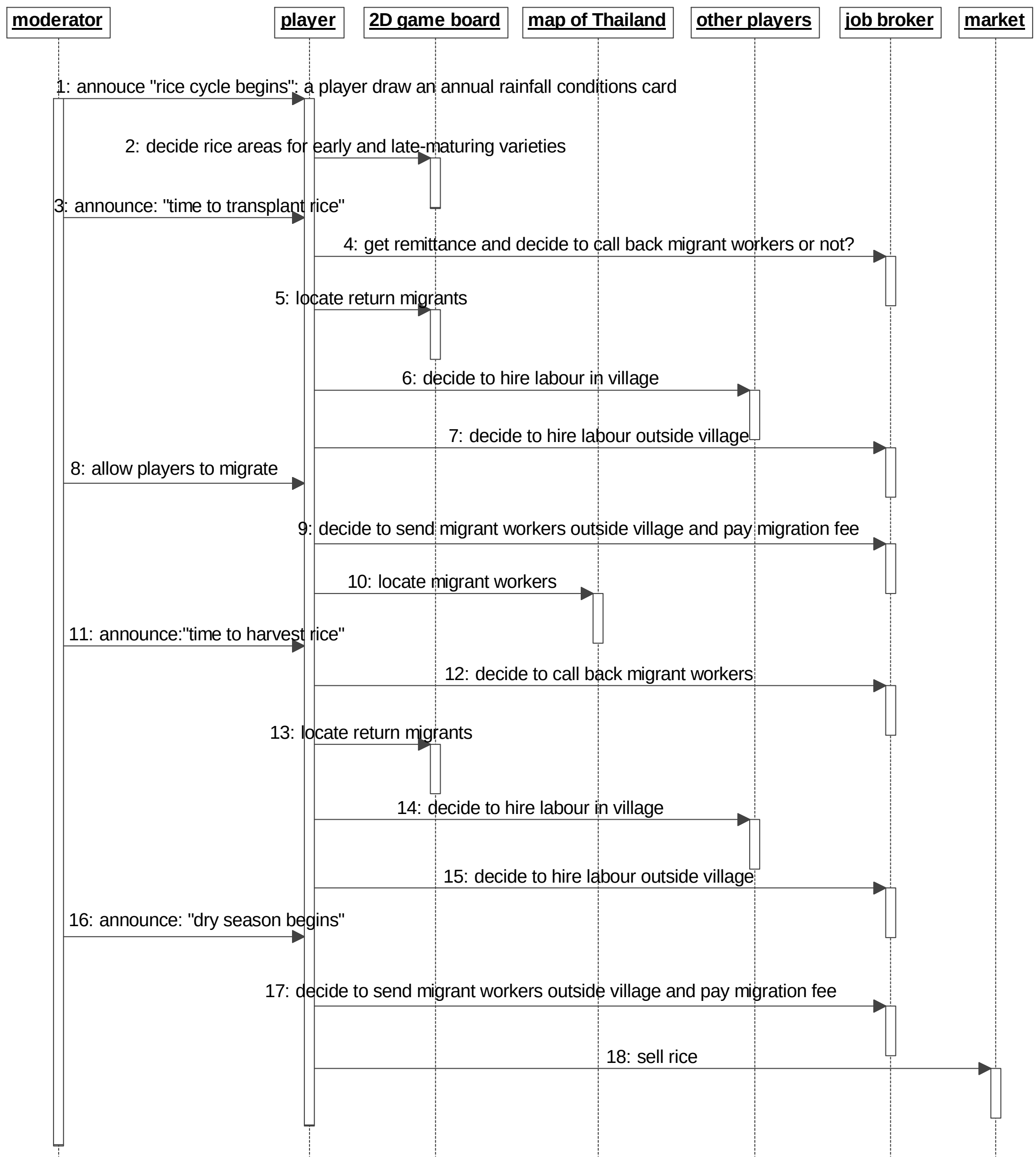


Figure 9.3 UML sequence diagram of the first RPG showing the successive activities implemented by the different game entities throughout a crop year.

The stochasticity was predefined for two annual rainfall conditions (wet and very dry), and three chance cards that stipulated the level of wage received (low, moderate or high). These wage level chance cards were designed to take into account the risk of varying economic returns on migration. A low wage card led to a low remittance later on. The rainfall and wage variables were drawn by players during the gaming session. The diversity of farmer types was taken into account when two villages were assigned into groupings of five and six households respectively in the gaming session.

9.2.1.3. Details

Initialization

The initialization had five households in village 1, and six households in village 2. Each household had different means of production as specified in Table 9.1. One household had two players. There was no type C farmer in village 1 because a sub-type C1 farmer did not come. The gaming session started; the players allocated family members to be on-farm workers on a 2D game board, and migrant workers on a map of Thailand. The gaming room was set as shown in Figure 9.4. The players in each village were separately located on the players' benches.

Table 9.1 Players' characteristics at initialization.

Village	*Player*	*Farm type*	*Farm land area (ha)*	*Farm pond (m^3)*	*Household size*
Village 1	1	A1	1.6	no farm pond	3
	2	A1	2.6	300	6
	3	A3	3.2	1,350	4
	4	B1	9.0	2,400	6
	5	C2	8.8	3,840	5
Village 2	6	A1	2.4	144	5
	7	A2	3.2	500	5
	8	A2	1.6	158	4
	9	A3	4.8	240	8
	10	A3	4.0	450	9
	11	B2	6.7	2,200	5

Inputs

Wet and very dry conditions were annual climatic inputs. The sale price of glutinous and non-glutinous (8 baht per kg for non-glutinous KDML 105 variety) at market was based on information obtained from local farmers.

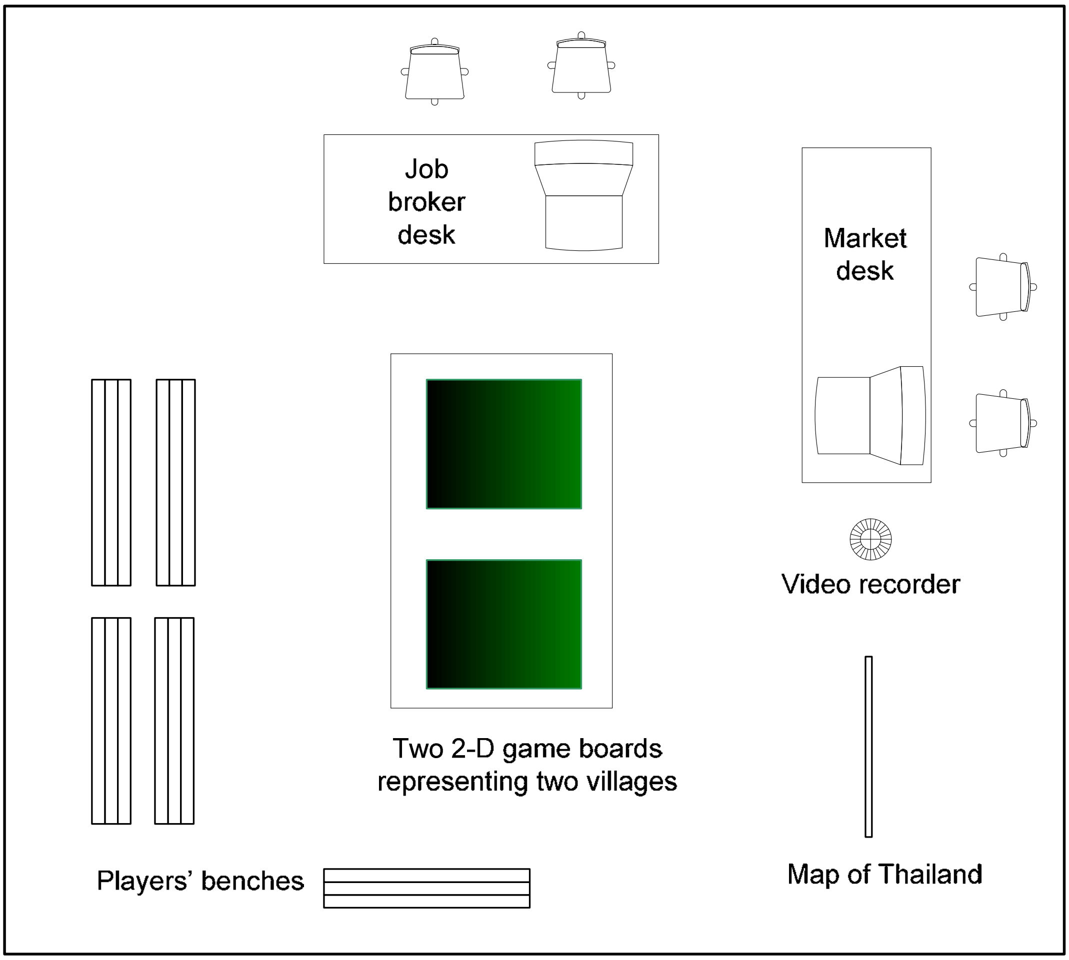


Figure 9.4 Setting of gaming room for first RPG session on 9-10 July 2005 at Ban Mak Mai school, Det Udom district, Ubon Ratchathani province.

Submodels

The submodels correspond to the five main steps played by participants during one round of play in the session (Figure 9.2). In this RPG session, the annual rainfall conditions card was drawn by a player at the beginning of each crop year.

Allocation of rice areas

Players allocated the size of their paddies for glutinous and non-glutinous rice. A game assistant recorded each player's decisions on a notepad (one game assistant per two players; see Figure 9.5).

Figure 9.5 The first RPG gaming session on 9-10 July 2005 at Ban Mak Mai school, Det Udom district, Ubon Ratchathani province, **Top left:** a player drawing an annual rainfall condition card; **Top right:** the 2D game board to allocate rice areas and on-farm workers. **Bottom left:** a game assistant locating migrant workers on map. **Bottom right:** players' decisions recorded by game assistants on stickers and pasted on the players' notepads**.**

Labour at transplanting and receiving remittance

The moderator announced that it was time to transplant. To manage labour, players were allowed to contact other players to get additional farm workers if needed. If none of them was available, players who needed extra labour had to hire labour from other villages at the job broker desk. Once a player finished managing labour for transplanting, he/she went to the job broker desk to receive remittance if there were migrant workers in his/her household (Figure 9.6).

Figure 9.6 The first RPG session on 9-10 July 2005 at Ban Mak Mai school, Det Udom district, Ubon Ratchathani province, **Top left:** a player receiving remittance at the job broker desk; **Top right:** Excel spreadsheet operated by the job broker to manage labour and compute remittance and migration fees. **Bottom left:** a player selling rice at the market desk; **Bottom right:** Excel spreadsheet operated by the market manager to compute income generated from rice sales.

Transplanting rice, and allocating on- and off-farm labour

After completing transplanting during this step, players were able to allocate their members to work outside the village via the job broker desk. The players were also supposed to pay migration fees (travel and job application costs etc.) if they decided to send someone to work outside of the village, but this minor step was missing during the gaming session. The players then had to designate a receiving destination for each migrant worker, and draw a wage level chance card. All decisions and cards drawn were recorded in a pre-designed Excel spreadsheet used by the job broker (see in Figure 9.6).

Labour at harvest and paying migration fees to job broker

Labour management at harvest was similar to the transplanting stage. At the end of the harvesting, the players were able to allocate members who wanted to migrate at the job broker desk. The migration fee was paid and a wage level card was drawn if someone in a household decided to migrate. All decisions were recorded in the job broker Excel spreadsheet (Figure 9.6).

Computing household income at market desk

Rice yields were computed according to the rainfall conditions in a pre-designed Excel spreadsheet used at the market desk (see in Figure 9.6). Rice yield was 2.5 t-ha^{-1} in a wet year and 1.8 t-ha^{-1} in a very dry year. Based on individual harvested rice areas, different data for total rice produced were given to each player, and he/she had to decide how much rice they wanted to sell at the market desk. Fake money was paid to players for rice sales. All data were kept in the market Excel spreadsheet. After all players had completed the sale of their rice, a new crop year could begin.

9.2.1.4. Results from the First RPG Session

The diversity of farming systems plays a major role in maintaining the local labour market since different farm types have different cropping calendars and farm sizes. Due to their small paddies, type A farmers can complete their transplanting and harvesting faster, and are thus able to be hired by their neighbours. In the gaming session, it was found that interactions between large and small farm players occurred when they had to negotiate labour costs. The players belonging to type A farmers (small holders) were hired by the players belonging to farm type B who had a high farm size per labour ratio. With this available employment opportunity, a few of the farm type A players decided to migrate after transplanting had been completed.

The farm type C player managed his family labour without hiring extra farm workers when rice was produced. His strategy was to grow various rice varieties. According to the different agronomic traits of each rice variety, the harvest time is different. The type C player distributed his family labour accordingly. Permanent migration was found in type B and C farming households. Even though the payment of migration fees after transplanting was not simulated, those players said that this missing minor step did not affect their migration decision.

Players' adaptation under different climatic conditions: change of rice area allocation, number of migrants and migratory patterns.

Regarding rice production in relation to climatic conditions across the farm types, players did not change the proportions of their glutinous and non-glutinous rice paddies when playing in the wet year condition. Such a change was observed when the very dry year card was drawn in the fourth year (Figure 9.7).

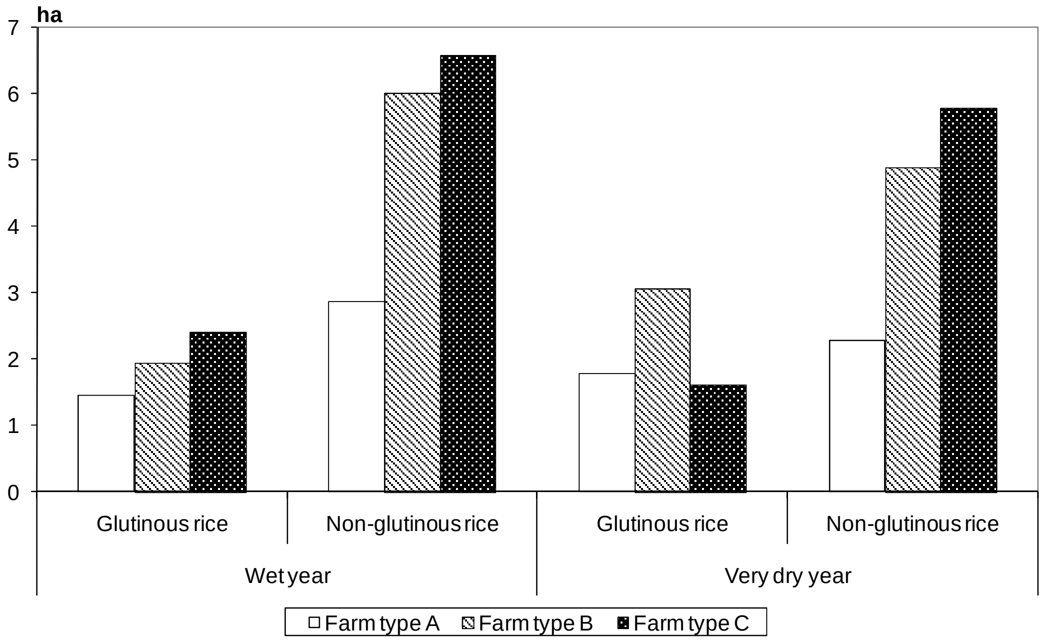


Figure 9.7 Amount of area allocated to different rice varieties in relation to climatic conditions across farm types in the first RPG session on 9-10 July 2005.

More glutinous rice for consumption was planted and less non-glutinous rice for sale as a general strategy to reduce the risk of drought on rice productivity and household food security. The priority of these players, who are of Thai-Lao ethnicity, is to secure family food stocks if they believe that rice yields may not be enough as a result of drought for example. However, only the type C player decreased both glutinous and non-glutinous rice-growing areas. With more market oriented objectives, the type C player usually sells both rice varieties. When facing very dry years, both varieties were produced less to minimize the risk of productivity loss, but the glutinous rice produced was still enough for family consumption.

Regarding labour migratory patterns in relation to climatic conditions across the farm types, all participating farmers decided to send their members to work more in the very dry year because of inadequate water availability for farming (Figure 9.8). In this situation, the players lost their income generated from rice sales. Thus, the off-farm income from migrant workers was needed to compensate income losses. Type A players indicated that they recalled seasonal migrant workers to help produce rice because of the financial burdens of hiring additional labour.

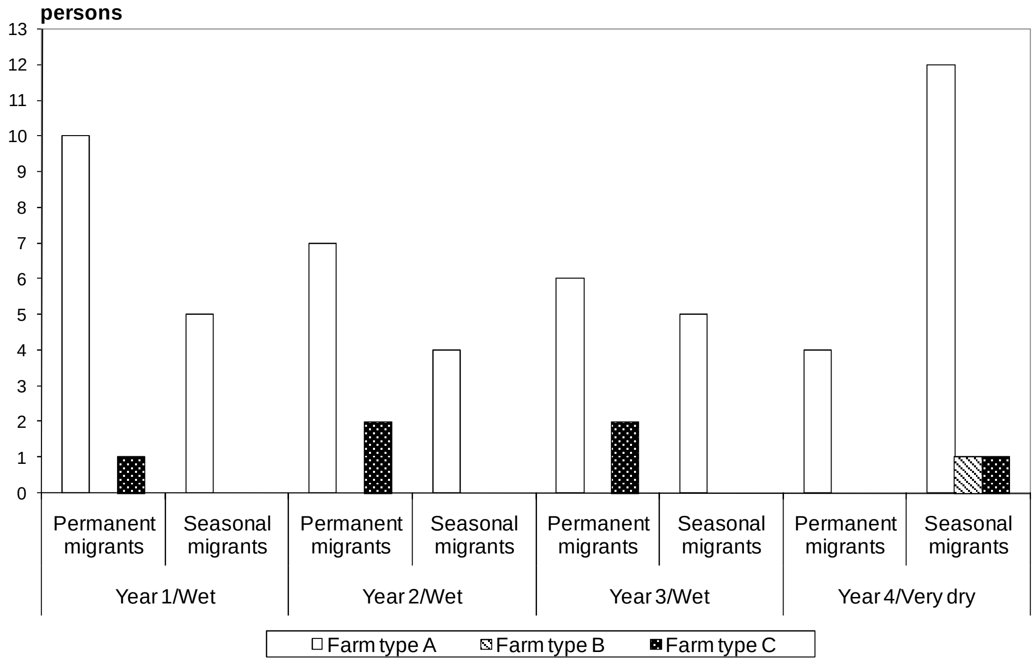


Figure 9.8 Number of migrant workers categorized by migratory patterns in different annual climatic conditions across farm type in the first RPG session.

Because type B players had higher land per labour ratio, none of their family members were migrant workers in the wet year condition. The migratory pattern was more-permanent on farm type C as migrant workers did not return to help family during the rice production cycle. However, a seasonal migrant belonging to the type C player was found in the very dry year, a year in which the player had no permanent migrants. The player explained that this was because the permanent migrant worked aboard and it was the end of a 3-year working contract. He had to return home in the very dry year, so he decided to seasonally migrate to work in non-farm sectors. This reflected the fact that the participating farmers played the game according to what they would actually do in reality.

The results from this RPG were used to enrich the original conceptual diagram. Based on the modified conceptual diagrams, a prototype ABM was constructed to represent stakeholders' decision-making processes. During the plenary session, the players suggested to have another workshop with new types of players: migrants returning home during the Thai New Year in 2006. Besides that, variations in water availability (prolonged drought and water resource improvements) were not explicitly introduced in the first RPG session. The second RPG session was organized to investigate the impact of variations in water availability on players' farm and labour management decision-making processes and to consequently improve the conceptual model. The participants' requests were also taken into account.

9.2.2. The Second RPG Session

9.2.2.1. Overviews

The purpose of the second RPG session was to (i) validate the research team's understanding of land/water use and labour management with a new migrant player, and (ii) investigate the players' decision-making processes under two successive very dry years, and irrigation canal scenarios. The state variables and scale, as well as process and scheduling was similar to that of the first RPG. This time, a sequence of six successive rounds of play with different rainfall conditions was performed: a first wet year, followed by two successive very dry years, and then a wet year, followed by a dry and very dry year with access to an irrigation canal respectively.

9.2.2.2. Design Concepts

The design concepts were also similar to that of the previous RPG. To take into account the unpredictability of rainfall conditions, a rainfall card was drawn after the players had already allocated rice areas for each variety. The purpose was to observe how players managed unpredictable rainfall conditions after allocating rice areas. The number of migrant workers was expected to decrease as the players adapted their farming strategies to produce more farm commodities when the irrigation canal scenarios were played.

9.2.2.3. Details

Initialization, inputs and submodels were not different from that of the first RPG. For the irrigation scenario, an irrigation canal was presented, and I presumed that the water was always available for the players.

9.2.2.4. Results from the Second RPG Session

This participatory modelling workshop was organized on 20-21 April 2006 after a period of prolonged drought (2004-2005 crop year). Most of the village's migrant workers did not return since RLR production could not start. Thus, only one returned migrant could join this workshop. The returned migrant player's farm and labour management decisions were not different from decisions made by his parents who had participated in the first RPG session. He explained that the farm and labour management decisions were usually made with the input of household members. In particular, it was a collective agreement if someone in his family was sent to work outside of the village.

Unlike the first RPG session, rice areas allocated for each variety were not different in the first wet year and in the second very dry crop year of the second RPG session. However, similar rice area allocation to that of the very dry year of the first RPG session was found in the subsequent very dry year (third year of the second RPG session). The players explained that they would not be able to adjust rice areas to fit the very dry conditions of the second year played after the rainfall card was drawn because the nursery was already established. In this case, it was thought that a second nursery establishment would be needed if the rice seedlings died as a consequence of the drought. But once they experienced the unfavourable conditions, they adjusted their rice areas in the following year (forth year of the second RPG session) to grow more glutinous but less non-glutinous rice. The reasons given for this course of action were the same as those of the first RPG session.

The introduction of an irrigation canal in the fifth and sixth crop years stimulated the players to think more about the opportunities of growing cash crops and vegetables in the dry season. The results (see in Figure 9.9) show that type A players were the most responsive users under this scenario, growing vegetable crops after rice. Farm type B and C players became more responsive in the sixth year because they had observed that more dry-season crops were produced by other players in the fifth crop year. However, they could not plant their desired amount of dry-season crops because the main source of labour supply, type A farmers, was actively engaged. Thus, the improvement of water infrastructure alone may not efficiently support all farmers in their attempts to intensify their farm production because it may induce problems of labour scarcity.

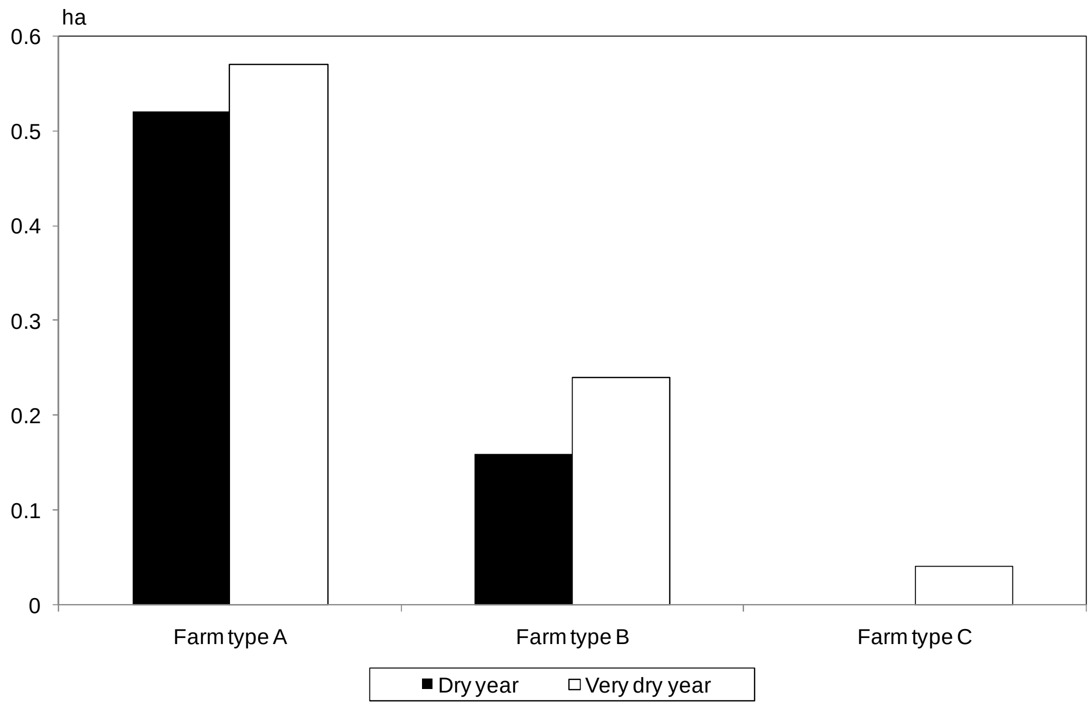


Figure 9.9 Average dry season crop area across farm types after the irrigation canal scenarios were played in the 5th and 6th crop years in the gaming session on 20-21 April 2006.

The number of migrant workers also decreased when the irrigation canal scenarios were played (Figure 9.10). This was because players needed farm workers once they decided to produce more farm goods (vegetables, cash crops etc.) in the dry season. The type C player had no migrants in the fourth year because migrant workers returned home after their job contracts abroad ended. But a member decided to sign another work contract and migrate to work in the fifth year. The game rules were slightly modified: the wage level chance card was removed in the irrigation scenario gaming sessions because the players did not take different wage levels into consideration when deciding to migrate.

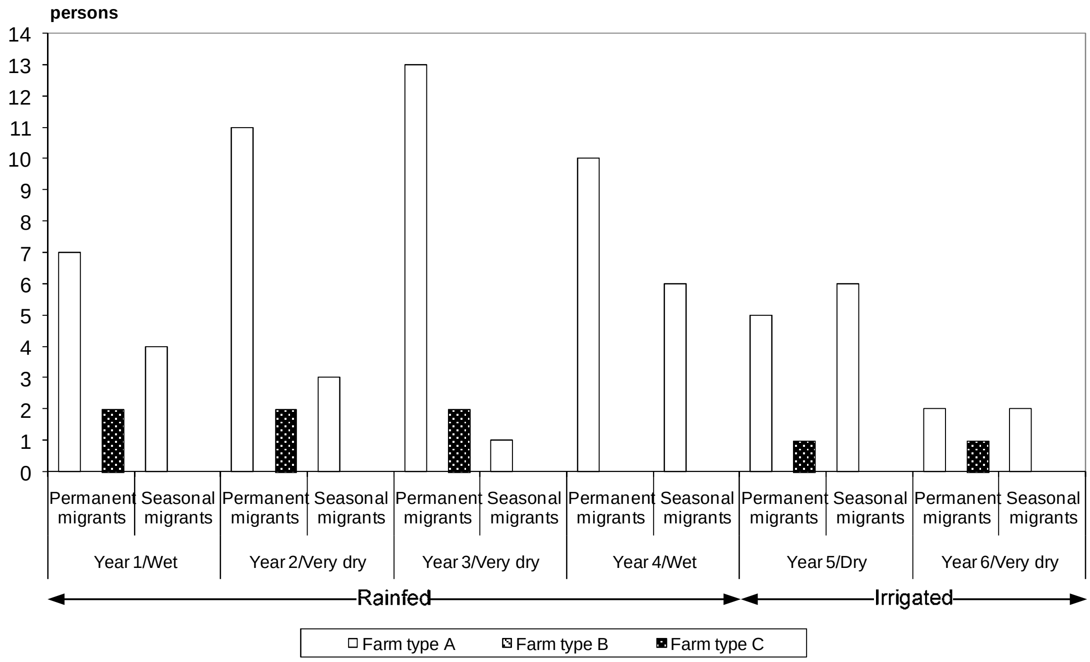


Figure 9.10 Number of migrant workers categorized by migratory patterns across farm types under different water availability conditions in the second gaming session on 20-21 April 2006.

During the individual interviews, players asked to replace the irrigation canal with farm ponds and artesian wells; this was considered to be a more feasible, realistic water improvement scheme for their village. Broad annual rainfall conditions did not allow the research team to investigate the dynamics of each main rice-growing activity, especially the players' water use strategy. In actual circumstances, rainfall distribution is more important than its total volume because the players make timely decisions under current rainfall conditions as to when a given activity should be performed. I also found difficulty in validating the decisions to use water from players' water sources to alleviate drought effects in this RPG session. Because of this limitation of the initial gaming sessions, a new RPG was designed to better represent the interaction between water dynamics and farm management (rice practices and labour use).

9.2.3. The Third RPG Session

9.2.3.1. Overviews

The purposes of the third RPG was to (i) to improve understanding of players' water uses and labour migration strategies across farm types under different water availability conditions, (ii) use that knowledge to improve agents' water use rules in the Lam Dome Yai model, and (iii) introduce players to learning through simulations of scenarios prior to introducing full ABM simulations. The game was designed to be as simple as possible so that 11 households (21 players) could play it with little help from two game assistants. No Excel spreadsheet was used. Players directly recorded their decisions on three pre-designed sheets: crop establishment, harvesting, and dry season sheets respectively.

The size of a community pond was a new state variable. It was 20 times larger than a standard farm pond (1,260 m^3) built by the ALRO, Ministry of Agriculture and Cooperatives. All players were able to freely access water from this community pond. The three main steps of the game are shown in Figure 9.11. The process and scheduling of the third gaming session is shown in the UML sequence diagram (Figure 9.12). The game scheduling proceeded on a weekly basis. Weekly rainfall conditions were displayed by pasting related pictograms on the calendar board; players were asked what decision they made regarding rice production after looking at the weekly rainfall conditions. Two scenarios were played as follows: (i) individual farm ponds under a succession of wet, very dry and dry years respectively, and (ii) free access to a community pond in a dry year followed by a very dry year.

9.2.3.2. Design Concepts

Farm type A players were expected to adapt to produce more farm goods during the community pond scenarios. Fewer migrant workers were also expected because of the demand for more labour to produce more farm products once water was made available. It was also expected that water sharing strategies would emerge during the community pond scenario.

Figure 9.11 The three main steps designed in the third RPG.

9.2.3.3. Details

Initialization

Figure 9.13 shows the setting of the gaming room. To promote knowledge exchange, players were located around a table. The players from the second RPG participated again in the third RPG session. Players drew the sizes of their paddy fields by painting glutinous rice areas red (early maturing) and non-glutinous (late maturing) rice areas black on the crop establishment sheet, shown in Figure 9.14. After all players had completed their drawings, the moderator began to reveal rainfall conditions week by week. The moderator explained how to draw water levels by using a paddy and farm pond water levels bulletin board that depicted five quantitative water levels with qualitative descriptions in Thai (Figure 9.15). For instance, the players drew the water level at half of the pond's volume (before pumping) if they believed that there would be enough water to be pumped to supply their nursery.

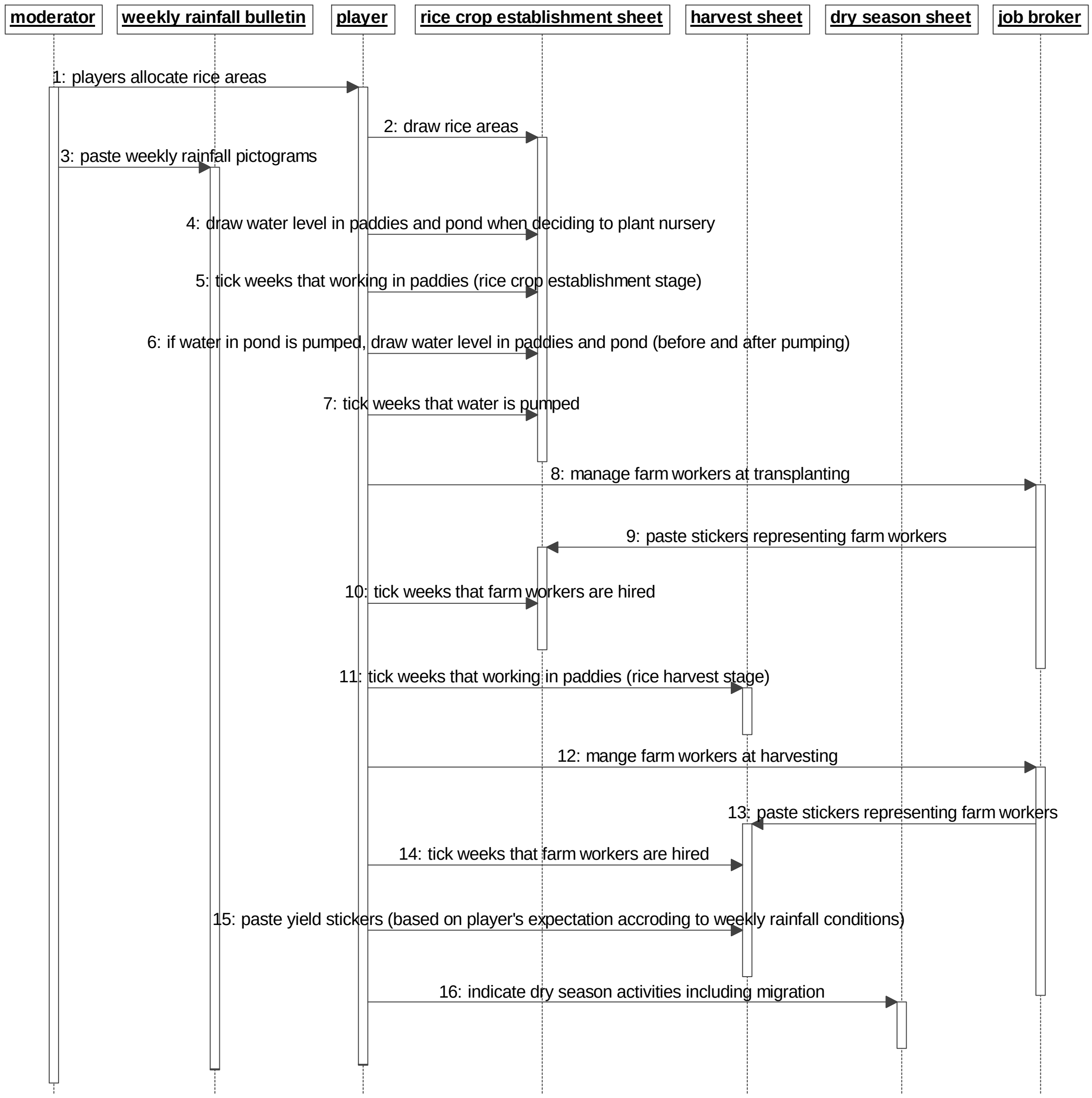


Figure 9.12 UML sequence diagram of the third RPG showing successive activities among its entities throughout a crop year.

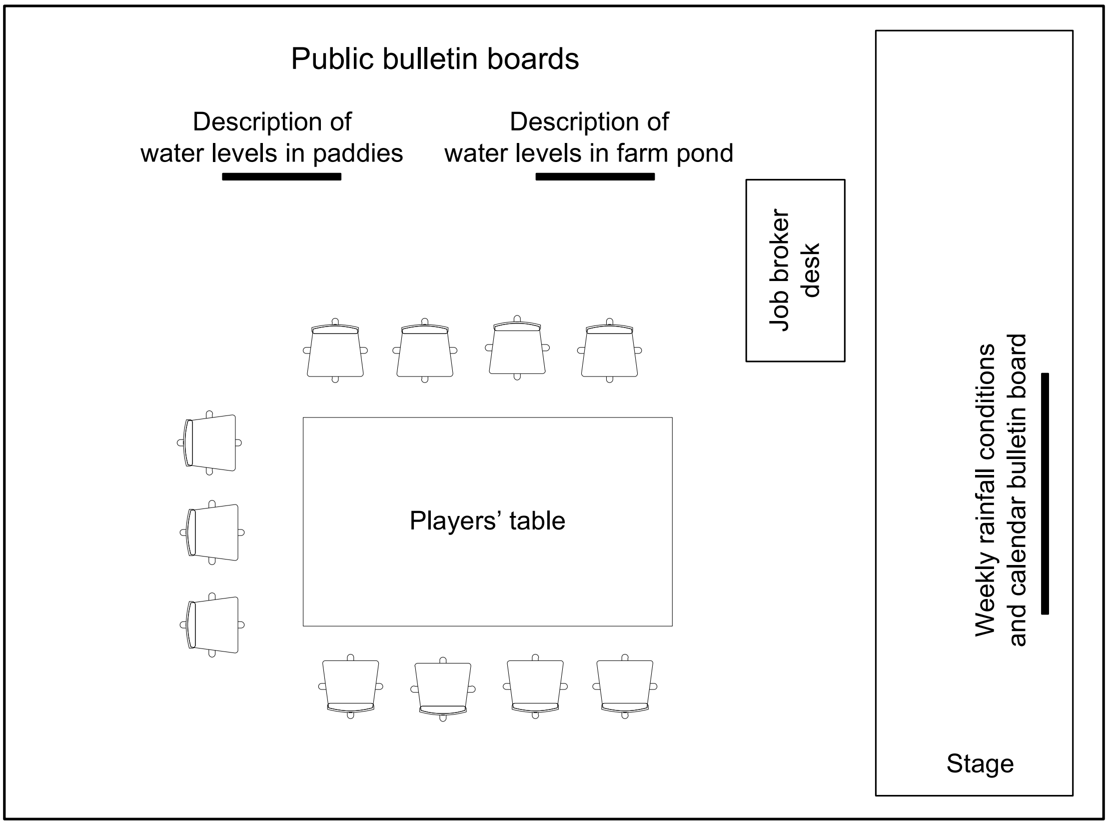


Figure 9.13 Setting of the gaming room for the third RPG on 10-11 October 2006 at Ban Mak Mai community building, Det Udom district, Ubon Ratchathani province.

Inputs

Weekly rainfall conditions shown as pictograms were pasted on the 52 week calendar board (Figure 9.15). The amount of weekly rainfall quantity determined four climatic conditions based on thresholds as shown in Figure 9.16. These thresholds were defined according to the average of 27 years of actual rainfall data in the wet season (April to September) obtained from the regional meteorological centre located in Ubon Ratchathani province. Rainfall data in the dry season was not used because the rainfall quantity during the dry season is very low (almost zero). If it had been used, the threshold values would have been too low. Based on climate records, three years of actual rainfall data were selected: 1972, 1975 and 1989 to represent wet, dry and very dry years respectively. To help players memorize weekly rainfall conditions, weekly rainfall pictograms were not removed from the calendar.

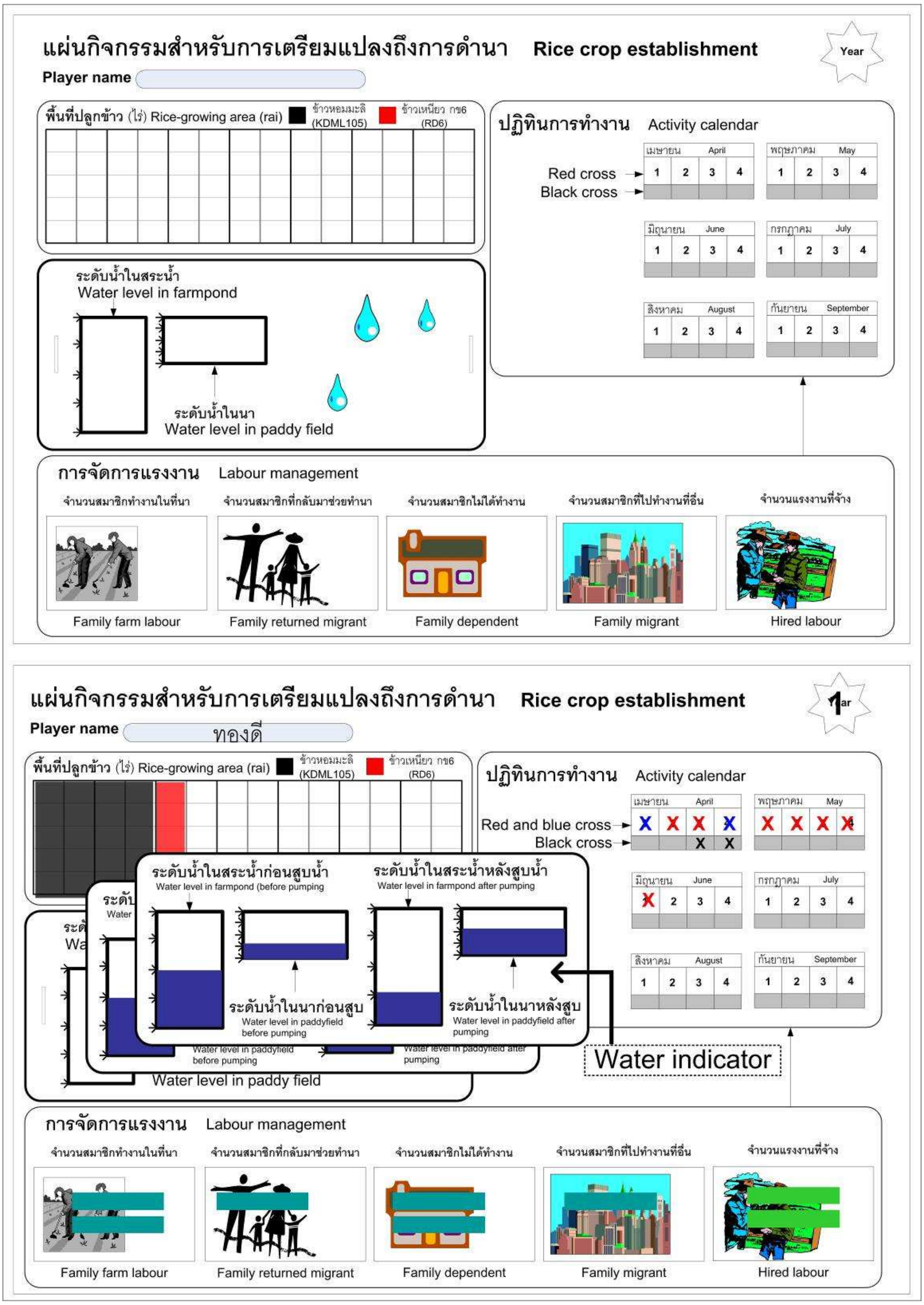


Figure 9.14 Crop establishment sheets used to record a player's decisions from nursery establishment to transplanting, **Top:** a blank sheet. **Bottom:** a sheet completed by a player.

Figure 9.15 Bulletin boards used to provide information to the players, **Top:** weekly rainfall pictograms on a calendar. **Bottom:** descriptions of water levels in pond (left) and paddies (right) under different situations.

Weekly rainfall threshold (mm)	more than 180	between 90 and 180	between 70 and 90	lower than 70
Weekly climatic conditions	very wet	wet	dry	very dry
Pictogram used				

Figure 9.16 Thresholds used to characterize weekly climatic conditions and pictograms used in the game.

Sub-models

Rice-crop establishment

Each simulated week, players were asked what they would do after weekly rainfall conditions were announced. Once the players decided to work in their paddies, they had to indicate whether they wanted to use water from their farm pond or not. If water was pumped, a blue mark had to be made on the activity calendar section of the crop establishment sheet. Once the blue mark was drawn, players needed to define water levels in their pond and paddies before and after water was pumped. The players received small pieces of paper, which were called “water level indicators”, so that they could overlay a new “water level indicator” on the previous one when they decided to pump water more than one time. The number of the water level indicators related to the blue marks in the calendar section, indicating how many times a player pumped water from the pond. If no water was used but players were working in their paddies, a red mark was made (Figure 9.14). Another black mark was drawn in grey boxes indicating that players hired labour in that week.

Family workers were managed by the players with specific colour stickers for each household. The light blue stickers are shown in figure 9.14. One sticker was equivalent to one worker. Players were able to hire other players as extra labour. A player who was hired had to paste his/her sticker in the hired labour box of his/her employer. If additional labour from other villages was hired, players had to manage this situation through the job broker. Special stickers with two colours were used to indicate labour from outside the village.

Rice harvesting

Similar procedures were used as above. Once players decided to harvest rice, they had to indicate their working weeks by red marks, and define the source and number of farm workers by using coloured stickers on the harvesting sheet shown in Figure 9.17. Players had to indicate how much water remained in the farm pond before harvesting rice and estimate their rice production at the end of crop year by pasting specific stickers on the harvesting sheet.

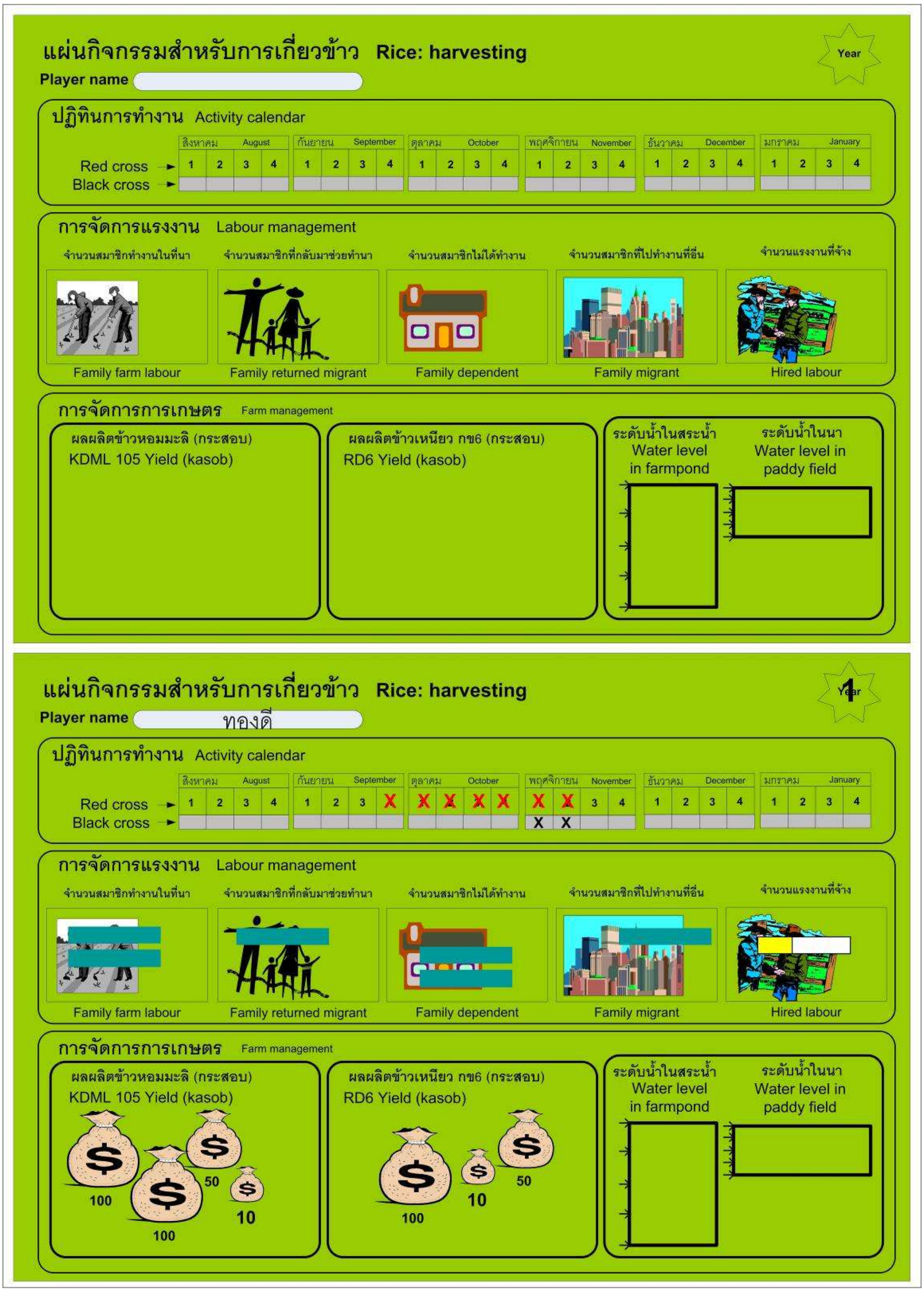


Figure 9.17 Harvesting sheet used to record a player's decisions during rice harvest. **Top:** blank sheet. **Bottom:** a sheet completed by a player.

Dry season activity

The focus of this step was labour management and farm production in the dry season. Players were asked to allocate family labour into three categories: working in village, migrating to the city, and just staying at home, as displayed in Figure 9.18. Players who wished to produce farm goods indicated key information on the dry season sheet (number of livestock heads, size of vegetable garden etc.). At the completion of the dry season activity, the moderator collected all the decision-making sheets, and started a new crop year. The same process and scheduling was used for the community pond scenario. However, instead of playing the game individually, players discussed how high the water level should be in the community pond. Players also had to negotiate how to best use the water from the community pond.

9.2.3.4. Results from the Third RPG Session

Water use strategies across farm types

Figure 9.19 shows the frequency of water pumping across farm types, with the exception of the sub-type A1 players who did not have farm ponds. The sub-type A2 players conserved water in individual farm ponds to mitigate possible drought effects on rice-seedlings. Less frequent water pumping from farm ponds among the sub-type A2 players was also noticed. However this was not the case for sub-type A3 players. Farmers belonging to this sub-type, by and large, have less water constraints in reality than other type A farmers. This sub-type A3 player, for instance, has farm land located in lower paddies, where water is ample enough to be used more often in the dry and very dry year. How sub-type A3 players played the game reflected their actual practices. Consequently, type A farmers’ water use strategies varied depending on where their paddy fields are actually located in reality and the water availability typically available in those locations.

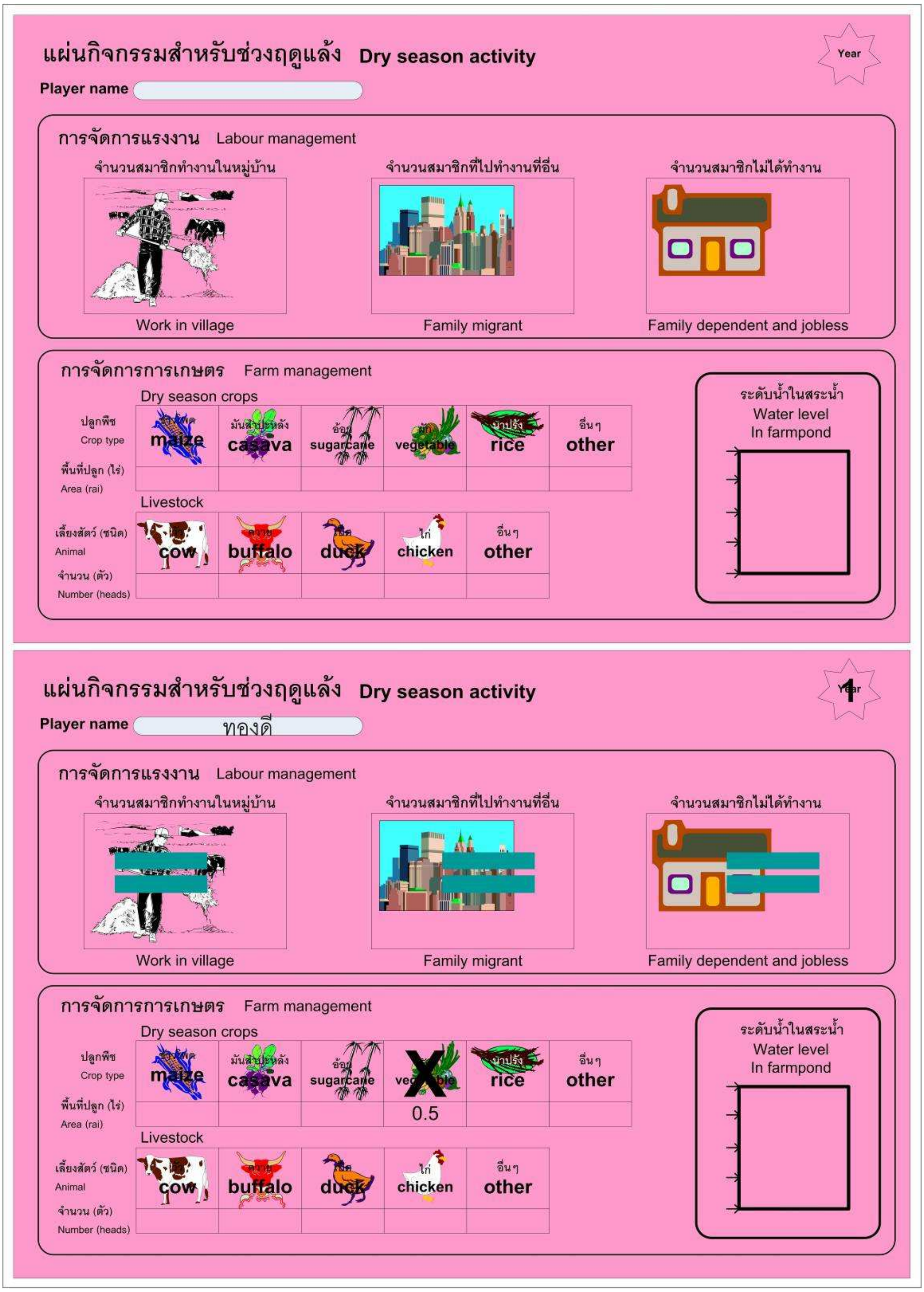


Figure 9.18 Dry season sheet used to record a player’s decisions after rice harvest. **Top:** blank sheet. **Bottom:** a sheet completed by a player.

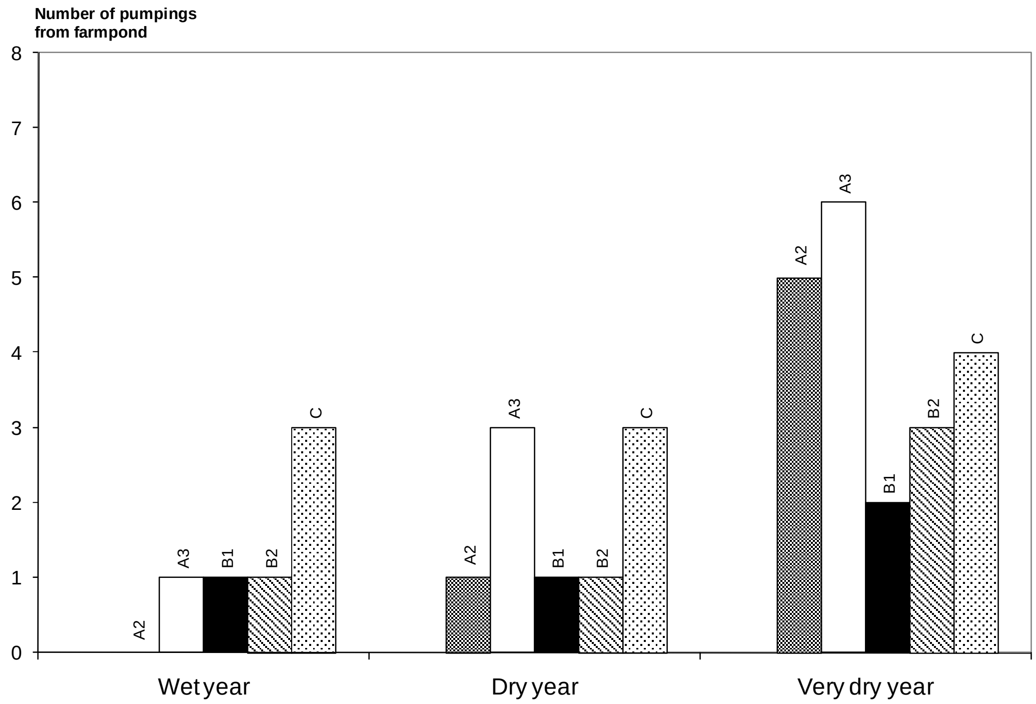


Figure 9.19 Water pumping from farm ponds across farm types in relation to climatic conditions during rice crop establishment (April to August) in the third gaming session on 10-11 October 2006.

Farm type B and C players used water from their farm ponds more frequently to grow healthy rice seedlings no matter what the climatic conditions were. However, the results from the very dry year shows that water was pumped on fewer occasions than for type A players. This was because the type B and C players had to manage large paddy fields and diversified non- rice farm products. They had to use water carefully to ensure that they would have enough for their farm production.

During the gaming session, it was observed that players directly discussing with each other what water levels would be required for the paddies and pond once deciding to establish a rice nursery. The description of water levels on the paddy and farm pond bulletin board helped the players to determine what water level they had to draw on the decision-making sheets.

Different decision-making processes in the individual and community pond scenarios

Figure 9.20 shows the results of the individual farm ponds compared to a new water infrastructure, a community pond. In the individual farm pond scenario, the water use strategies were different across farm types, which lead to different patterns of rice crop establishment. The farm type B and C players who had less water constraints than type A players decided to establish a nursery earlier, even in the very dry year. In the community pond scenario, all players had to discuss their perceptions of the water level at the time (simulated weekly) and collectively agree upon pumping water from the community pond. Almost all of the players decided to use water at almost the same time. This was because they were afraid that there would be no water left for them in the subsequent crop year.

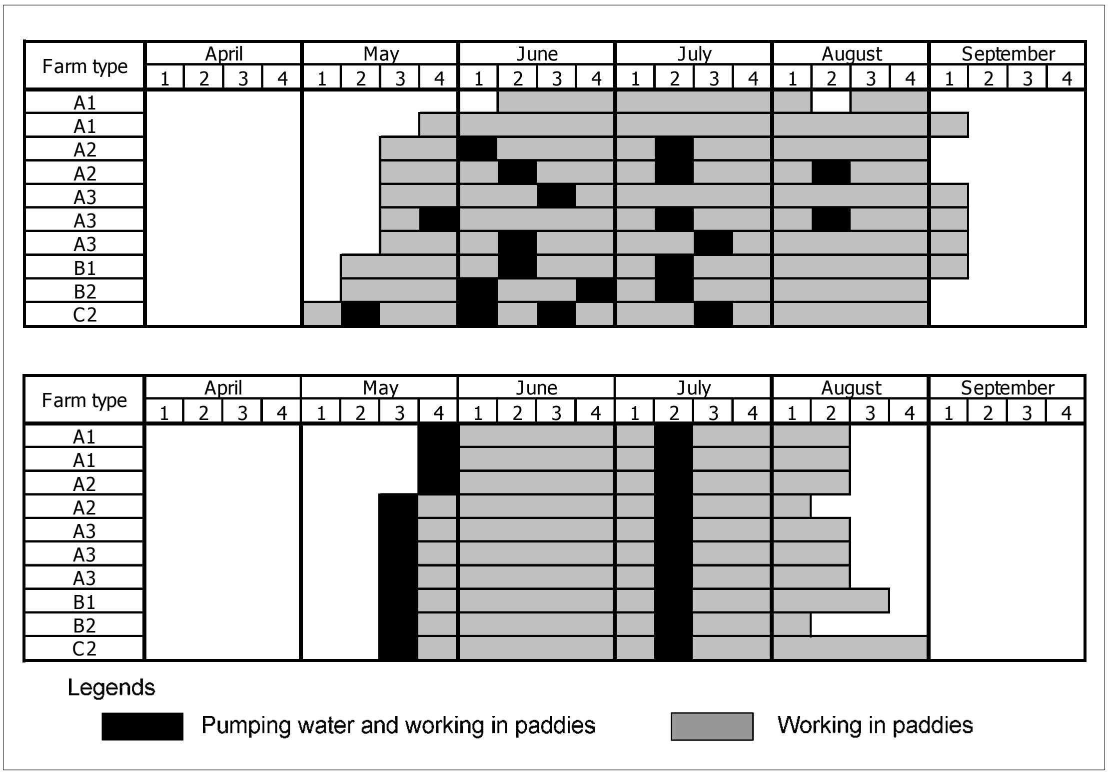


Figure 9.20 Water pumping from farm ponds and working in paddies over the weeks and months across farm types for the two scenarios, **Top:** individual pond use in the very dry year scenario. **Bottom:** community pond use in the very dry year scenario.

Nonetheless, three type A players decided to pump water one week after other players (they all discussed that move before telling us their decision). Because they had small areas of land (less than 3.2 ha), they needed less water to grow rice. They also wanted to be hired by their neighbours before starting their rice production so that they would have additional cash to spend on their rice production. This confirmed my preliminary findings that type A farmers considered wage as an important source of income, and that they are a key source of hired labour in this village.

The improved water availability through a community pond seemed to stimulate more dry-season crop cultivations for farm type A and B players (Figure 9.21). But smaller production areas were observed among type B players, a situation brought about by labour constraints. Only the type C player perceived that water in the community pond would not be enough to produce dry-season crops. The risk of growing dry-season crops with an inadequate water supply was too high, and he was simply not interested. Besides, he receives a high remittance from migrant workers. There is no financial pressure, especially the repayment of debts, pushing him to produce more farm commodities in the dry season.

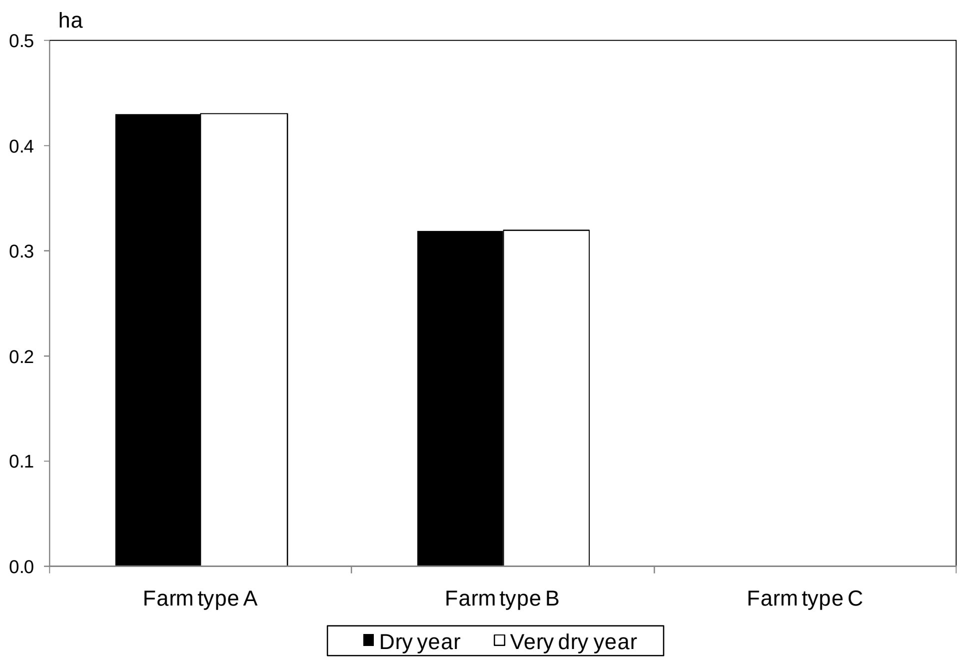


Figure 9.21 Average dry season crop area across farm types after the community pond scenario was played in the third gaming session on 10-11 October 2006.

By the end of the third RPG session, farmers acknowledged that it was easy for them to relate the simulated games to the reality of their situations, mainly because of the delivery of weekly rainfall information. Since the local farmers have experienced being participants in the "player-based simulations" of the RPG sessions, they are expected to be able and comfortable following and discussing computer simulations; they will be able to relate the "agent-based simulations" with their experiences. However, the weekly time step controlled by the moderator through the announcement of weekly rainfall was still too broad to examine participating farmers' decision-making processes because they make decisions to grow rice in relation to labour and water availability on a daily basis. Furthermore, the standard calendar based on the solar (western) system was not easy for them to follow because they are accustomed to using the traditional one based on the lunar system. These concerns were taken into account when building the ABM. To create better communication, this calendar needs to be modified to the lunar system, which is traditionally used by local farmers. To efficiently investigate the decisions and actions of local rice farmers, the weekly time step has to be replaced by a daily time step. However, the daily time step could limit the use of an RPG because the RPG would be too detailed, taking a very long time to play out. An ABM might be a promising tool to overcome this limitation.

CHAPTER 10

THE BAN MAK MAI AGENT-BASED MODEL

An ABM is a computational model that allows for the simulation of actions operated by autonomous entities (called "agents"), interactions among multiple agents and between the agents, and the virtual environment where they are located. From components interacting at the lower (micro) level of a MAS, system properties emerge at a higher (meso) level. Individual agents, whose knowledge and perceptions are limited, are presumed to be acting according to what they perceive as being in their own interest (Axtell, Andrews et al., 2003). Agents in an ABM may experience learning, adaptation, and reproduction (Bonabeau, 2001).

In the field of computer science, the research on MAS refers to game theory, complex systems, computational sociology and evolutionary programming. The idea of agent-based modelling was developed as a relatively simple concept in the late 1940s since it required computation-intensive procedures (Gilbert, 2008). A further step was made when the mathematician John Conway introduced the well-known 'Game of Life' operated by tremendously simple rules in a virtual world in the form of a 2-dimensional checkerboard (Conway, 1970).

ABMs are nowadays widely used to investigate how basic micro mechanisms generate macro structures (Epstein and Axtell, 1996). With such a perspective, relations and descriptions of general/system variables are replaced by an explicit representation of the micro features of a system usually considered in a discrete space-time (Gross and Strand, 2000).

The BanMakMai (BMM model) ABM was developed with the CORMAS (Common-pool Resources and Multi-Agent Systems)[15] platform, which was specifically developed to deal with renewable resource management. It uses Smalltalk object-oriented language under the VISUALWORKS environment (Bousquet, Bakam et al., 1998; Green Research Unit, 2003). CORMAS provides the developer with a built-in facility that includes a set of pre-existing entities and agent control procedures, and different types of interface to visualize simulation results.

Through the above mentioned collaborative modelling process, the BMM model was co-constructed to achieve a representation of the reference domain shared

[15] CORMAS and source code of BMM model are available at http://cormas.cirad.fr.

by all the participants in the modelling process, including researchers. A sense of co-ownership of the BMM model therefore emerged as a result of the collaborative model construction process. The description of the BMM model, and its verification and validation are presented in this chapter.

10.1. The Challenge of Describing an ABM

Describing the implementation of an ABM is often cumbersome: its structure, characterized by intertwined interactions and rule-based algorithms, is difficult to unfold. Compared to traditional equation-based models, ABMs are undoubtedly more difficult to describe, communicate and analyze. Traditional equation-based models are easy to communicate because they are formulated in the unambiguous and universal language of mathematics. Unlike mathematical models, computer simulation models such as ABMs have no standard language or protocol for communication, so published descriptions of ABMs are often hard to read, incomplete, ambiguous (without clear indication of rules and schedules), and therefore less accessible (Grimm and Railsback, 2005). Consequently, to reproduce an ABM from its published description remains problematic (Hales, Rouchier et al., 2003), which seriously questions the scientific status of such tools.

To help readers understand the structure of ABMs more easily, and enable them to re-implement such types of models, a standard protocol entitled Overviews-Design concepts-Details (ODD) has been proposed for the description of both individual-based models (IBMs) and ABMs (Grimm et al., 2006). IBMs differ from ABMs in that they generally model non-human entities interacting within an ecological system (Grimm et al., 2005), while ABMs often model human actors making decisions (Gilbert and Troitzsch, 1999). The description of the BanMakMai ABM below is, hence, based on the ODD protocol.

10.2. Description of the BMM Model

10.2.1. Overview of the BanMakMai Agent-Based Model

The first purpose of the BMM model is to inform readers about what is to be done with the model. Then, the low level state variables[16] of all entities (see Table 10.1) and the spatial and temporal scales outline the structure of the model. A UML class diagram showing the structure of the ABM completes this static representation (see Figure 10.1). Finally, all the processes that occur in the model are listed and indications about how they are scheduled are given in a UML sequence diagram (see Figure 10.4).

10.2.1.1. Purpose of the BMM model

The BMM model is a communication tool that is used by scientists and local RLR farmers to exchange knowledge about the interactions between land & water use and labour migration in the RLR environment of lower northeast Thailand and integrate that knowledge into local practices.

10.2.1.2. State Variables and Scales

The BMM model is made of five key interacting entities: Individual (Member), Household, Village, Rice, and Water tanks. Individuals (Members) and Households are rule-based agents representing local rice farmers from Ban Mak Mai village. In the BMM model, the heterogeneity of the household's aggregating member agents, whose age, gender, marital status and migration experience are different, depicts the diversity of existing farming households as they exist in reality.

The age of an individual (Member entity) influences its labour status and role (dependant, farmer, or migrant) while gender, marital status and migration experience influence an individual's decision to migrate or not. The age and the migration experience of an individual change over time. Figure 10.2 shows the relationship between the age and labour status (role) of an individual. The performance (area per day) of an individual performing the Farmer role also depends on the individual's age.

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[16] Low level state variables cannot be deduced from other state variables because they are elementary properties of model entities. For example, individuals might be characterized by age, gender, location etc.

The algorithm simulating the decision of an individual member to switch its role to migrant is described below in the "details" section of this chapter.

Table 10.1 List of parameters classified by entity indicating their default values and sources.

Parameter	*Default value*	*Unit*	*Source & main tool used*
Minimum age of farmer villagers	15	years	Field workshop based on BMM model in 2007
Maximum age of farmer villagers	65	years	
Minimum age of migrant villagers	17	years	Authors' farm survey in 2004
Maximum age of migrant villagers	45	years	Field workshop based on BMM model in 2007
RLR transplanted area	0.16	ha/day	
RLR harvested area	0.08	ha/day	
RLR transplanted area by young farmers	0.16	ha/day	
RLR transplanted area by old farmers	0.08	ha/day	
Age threshold for RLR transplanting	50	years	
Beginning of RLR nursery establishment	the Royal Ploughing Day	day	Field workshop based on RPG1
Average annual net income per household	20,000	baht	NSO, 2007
Average farm input cost excluding labour cost	20,000	baht/ha	OAE, 2007
Average annual consumption expenditure	9,600	baht/per capita	NSO, 2007
Paddy for self-consumption	350	kg/person/year	Authors' farm survey in 2004
Daily rainfall threshold to initiate RLR nursery establishment	30	mm	Field workshop based on RPG3
Daily rainfall threshold to start transplanting	20	mm	
Daily rainfall threshold to stop harvest for one day	10	mm	
Daily wage at RLR transplanting	120	baht/labour	Field workshop based on BMM model in 2008
Daily wage at RLR harvest	150	baht/labour	
Minimum daily rainfall of a wet day at nursery stage	10	mm	Field workshop based on ABM2
Duration of dry spell for water stress to occur in RLR nurseries	12	day	Field workshop based on ABM1
Average RLR paddy yield in Ubon Ratchathani province	1,970	kg/ha	OAE, 2007
Age of RLR seedlings ready for transplanting	30	day	Field workshop based on RPG1
Duration of transplanting after rice seedlings reach 30 days	21	day	Field workshop based on ABM2
Last week to establish RLR nurseries	3rd week of July	week	Field workshop based on RPG1
Last week for RLR transplanting	2nd week of September	week	
Starting date for harvesting of glutinous rice (RD6)	10th November	day	Bureau of Rice Research and Development, 1999
Starting date for harvesting of non-glutinous rice (KDML105)	21st November	day	
Maximum harvesting date to get high quality paddy	1st December	day	Field workshop based on BMM model in 2007
Maximum harvesting date to get fair quality paddy	10th December	day	
Farmgate price of high quality paddy	18	baht/kg	Thai Rice Mills Association, 2008
Farmgate price of fair quality paddy	12	baht/kg	
Farmgate price of low quality paddy	9	baht/kg	
Water quantity needed to establish a 0.04 ha RLR nursery	80	m^3	Field workshop based on BMM model in 2007
Water quantity needed to supply a 0.04 ha RLR nursery	40	m^3	
Depth of water storage tanks (farm ponds)	3	m	Authors' farm survey in 2004
Height of ponding tanks (paddy fields)	20	cm	
Minimum depth of water level needed in water storage tanks as percentage of water storage tank depth	10	%	Field workshop based on RPG1
Daily volume of water deducted from a ponding tank by the soil-plant system	10	mm	BMM model calibration

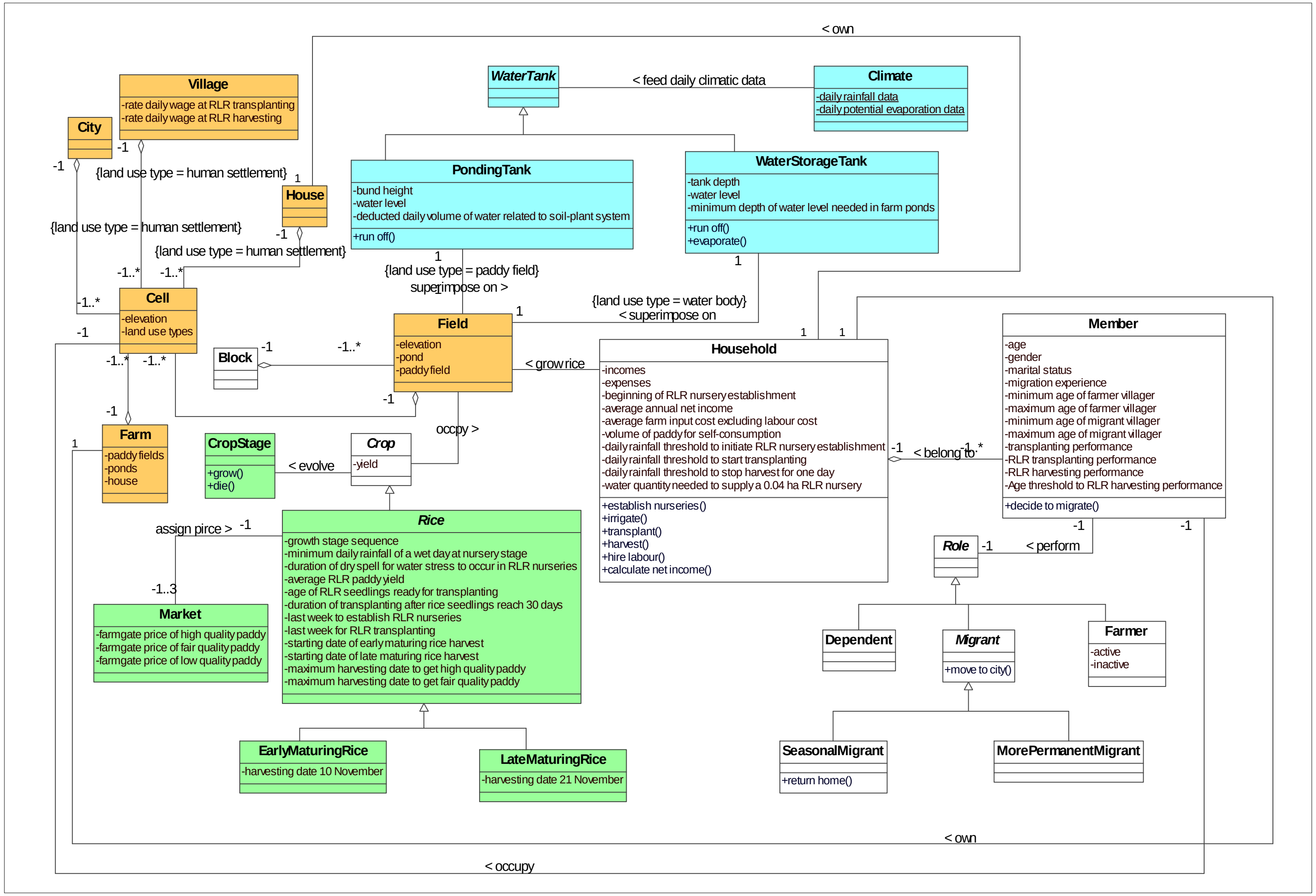


Figure 10.1 Structure and interlinked components of the BMM model represented by a UML class diagram showing the attributes and methods associated to each entity.

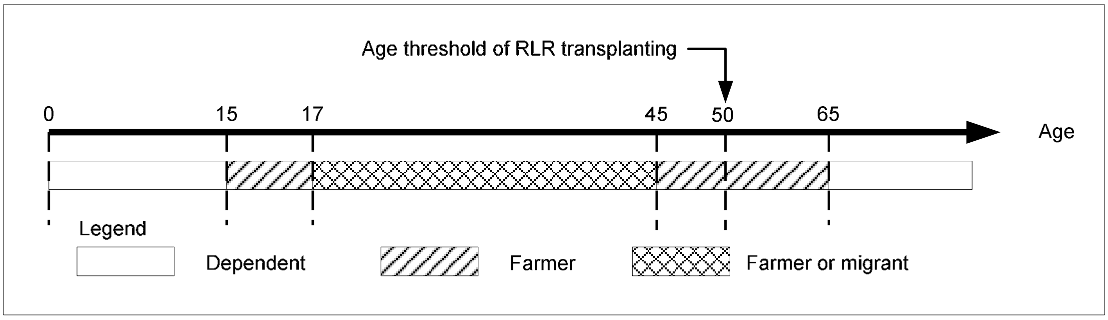


Figure 10.2 Relationship between the age of individuals and their labour status.

The Household entity, made of individual members, is a key decision-maker in the BMM model. All main RLR-producing activities are decided at this entity level by considering the need for and the availability of water whenever it is relevant (for instance there are thresholds of daily rainfall to start the nursery bed, to start transplanting and to pause harvesting; see Table 10.1). State variables embedded in this entity include average farm input cost (used in the calculation of income generated from rice sales), average annual net household income (used in the migration decision algorithm), and annual area of paddy for self-consumption.

The Village entity is an aggregation of household agents functioning as a registration desk where all potential farm workers are listed for hiring. The daily wages for transplanting and harvesting rice are also defined at this level. The Rice entity comprises two photo-sensitive late-maturing varieties: glutinous (RD6 variety) for self-consumption, and non-glutinous (KDML105 variety) rice for sale. The key dates and durations related to the successive phases of the RLR-based cropping system (seedling stage, transplanting, harvesting) are presented in Figure 10.3. For instance rice seedlings can be transplanted once they are 30 to 51 days old. After 51 days, the rice seedlings are too old for transplanting.

The lack of water at critical points of the cropping calendar (establishment and maintenance of nursery beds, start of transplanting) results in partial (maintenance of nursery bed) or complete (establishment of nursery bed and start of transplanting) failure. To facilitate the comparison of simulation scenarios, the yield is set to a constant value of 1,970 kg per ha (Office of Agricultural Economics, 2007). Three different selling prices of late maturing rice variety are set to represent a delay between maturity and harvest: the faster the harvesting is completed, the higher the quality of the paddy (see Table 10.1). The three different prices of rice also take into account the effect of the duration of harvest on the quality of paddy. The volumes of water needed to establish a nursery and to alleviate any drought effects, and the time constraints of rice-growing practices at each rice growth stage are also low level variables (see details in Table 10.1).

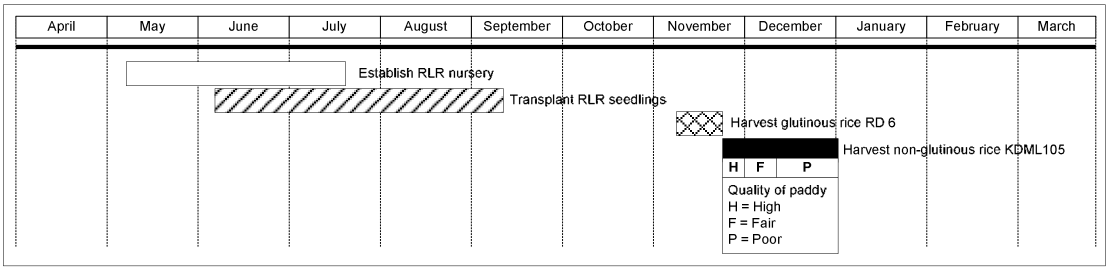


Figure 10.3 Rainfed lowland rice (RLR) cropping calendar in the BMM model.

In the BMM model, Water tank entities are either paddy field ponding tanks (20 cm deep) or farm pond storage tanks (3 m deep). The water level in the tanks is updated on a daily basis by adding the rainfall and subtracting the evaporation read from external data files (see below in the "input" section in this chapter). When the water level exceeds the height of a water tank, the overflowing water is shared among the lower level neighbouring water tanks (run-off). Additionally, an estimated constant volume (10 mm per day) is subtracted from the ponding tanks to account for water used by the soil-plant system. A minimum water level (estimated at 10% of storage capacity) is needed in the ponds. Otherwise a household cannot operate the irrigation function.

The spatial resolution was set to 0.04 ha (one *'ngan'*, a traditional Thai measurement of area), and is represented by a cell (the smallest homogeneous spatial unit of the model) on the BMM interface. Elevation ranges from 97 to 133 meters and represents a regular slope from lower to upper paddies. To represent a typical portion of a RLR ecosystem, 2 small (3.6 ha) and 2 large (7 ha) farms are plotted. Each farm is made of a collection of paddy fields in sizes ranging from 0.28 to 0.96 ha.

The BMM model is a discrete time step model. A daily time step was chosen because in reality, participating rice farmers adjust their decisions according to climatic conditions on a daily basis. However, to some extent this model is also event-driven since occurrences of water stress during the nursery stage trigger household agents' reactions. The time horizon was set to 5 years to enable an assessment of scenarios simulating diverse climatic situations to be carried out while limiting the impact of demographic change: within such a relatively short period of time, the reproduction and mortality of individual members, which are not the focus of this model, are not taken into account.

10.2.1.3. Process Overview and Scheduling

A simple hydro-climatic process aggregating rainfall, evaporation, run-off and soil-plant consumption is run on a daily basis to update the water levels in all water storage tanks and to determine water availability for rice cropping. The operations related to rice production are also considered on a daily basis by the household agents. Figure 10.4 shows the sequence of farming activities throughout a crop year that was set to start on the first of April. The key successive farming activities are as follows: establishment of RLR nurseries and production of seedlings, transplanting, and harvesting. After RLR harvest, each household computes the results of the rice season. This updated household income and the presence of dependants in the household is taken into account when each member makes migration decisions during the dry season.

10.2.2. Design Concepts

This section intends to specify how concepts such as stochasticity, adaptation, fitness (objective) and interactions are addressed in the BMM model. The BMM model is purely deterministic. Randomness would be inconveniently confusing when the main objective of the model is to enhance communication among participants.

Household agents are able to memorize daily rainfall conditions and therefore detect the occurrence of water stress in nurseries when the last effective rainfall occurred more than 12 days ago. Additionally, in agreement with the objective of managing rice production and paddy quality, household agents adapt to labour constraints and can hire extra farm workers at transplanting and harvesting if needed (they are able to anticipate the need).

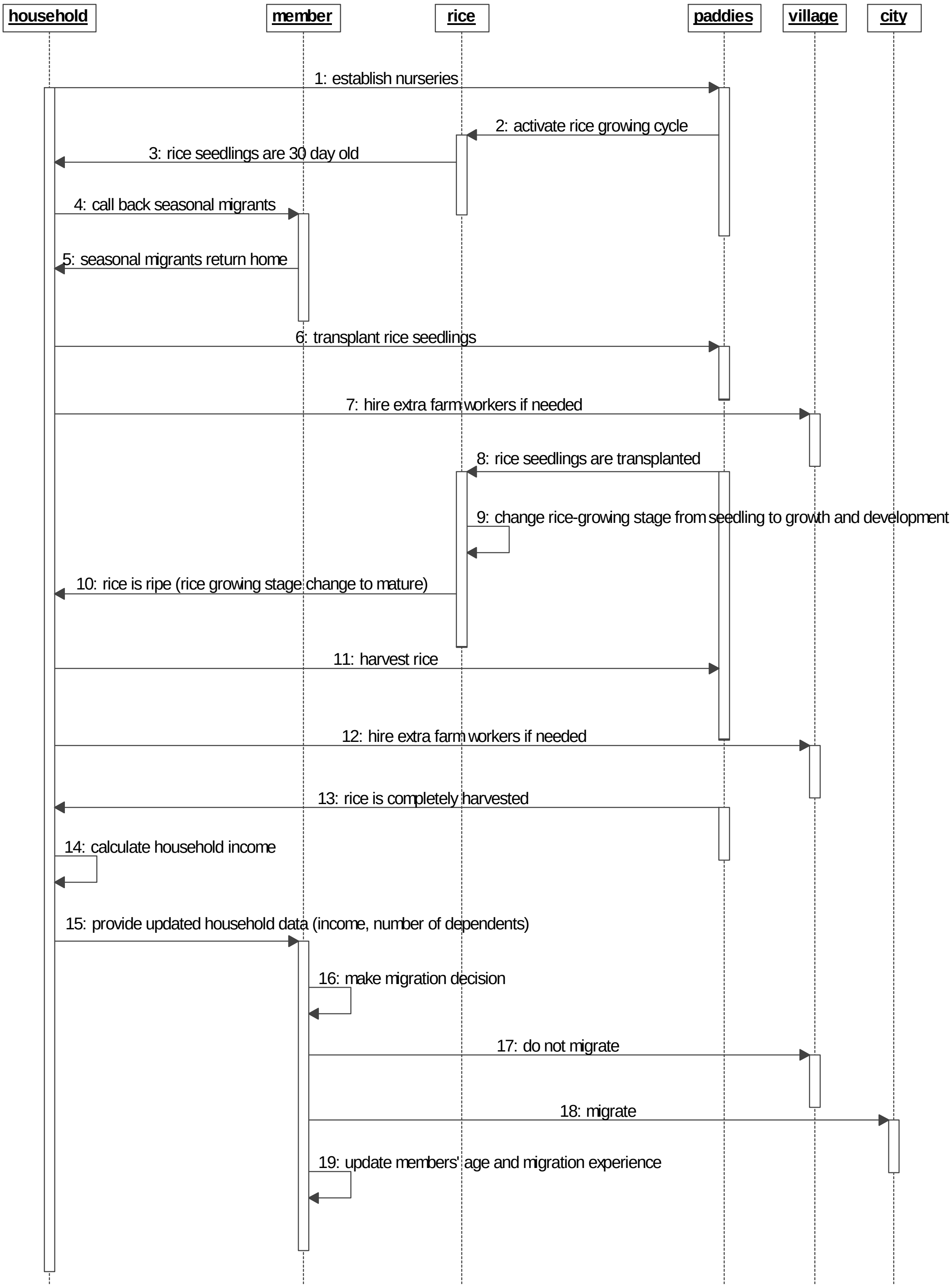


Figure 10.4 Scheduling of the BMM model operations during a crop year represented by a UML sequence diagram.

The BMM model integrates three aggregated social levels: individual, household, and village. A list of farm workers available for hiring is updated at the village level, and made accessible to all household agents. The household agents directly interact in the process of hiring extra farm workers.

Observation of visual outputs is an essential feature of collaborative modelling: for the farmers to be able to comfortably follow a simulation, a set of specific interfaces were developed. To facilitate the understanding of the chronology of a simulation, an interface depicting the traditional calendar was displayed week after week with the corresponding rainfall distribution (Figure 10.5). It also displays the dates of key ceremonies used as milestones by the farmers, such as the Royal ploughing ceremony in early May and the Thai New Year on the 13^{th} of April. Rainfall information is also updated on a daily basis, illustrated in the right corner of the simulation interface (close to household A2).

Water levels in farm ponds are also displayed on the BMM main interface to facilitate discussion and assessment by participating farmers (Figure 10.6). Other types of spatial settings are constant, and are used to indicate the role of their occupants (dependant, farmer, or migrant) via the use of different coloured pictograms.

To visualize what is happening at any time step of a simulation in a way that makes sense to the participating farmers, the interface representing the space includes other elements. As shown in Figure 10.6, roads are located at the highest elevation, next to upper paddies, while lower paddies are close to a natural stream located at the lowest elevation. Additionally, to allow for the visualization of the labour status of individual members by deduction from their locations, human settlements are also represented: one house per farm (location of dependent members), one village (location of unoccupied farmers) and one city (location of migrants).

Figure 10.5 Display of rainfall conditions on a daily basis (left) and weekly basis (right) on the BMM model main interface.

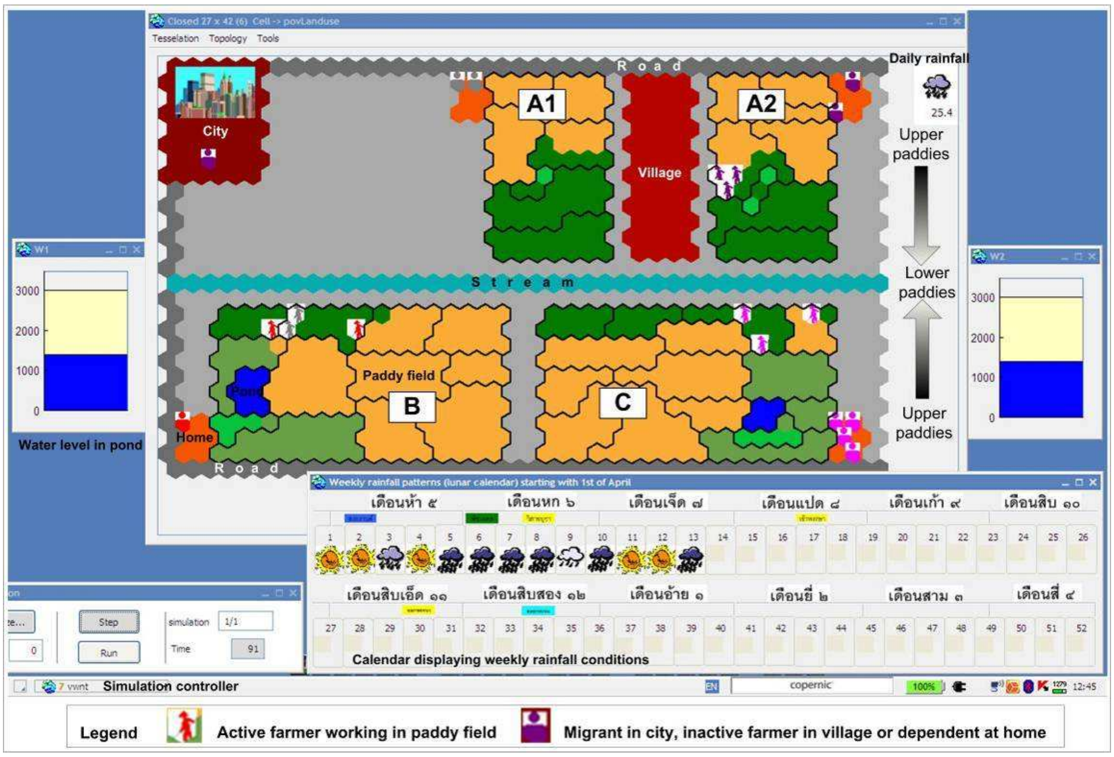


Figure 10.6 Spatial configuration of the BMM model representing two small farms (A1 and A2) and two large farms (B and C) during rice transplanting, and water level in farm ponds updated daily during simulation run.

The visualization of paddy fields changes according to the stage reached by the rice crop. For instance, during rice establishment, a light green colour indicates fields planted to glutinous rice (RD6) while dark green refers to non-glutinous rice (KDML105). Once the rice is ripe, yellow is used to indicate that it is ready to be harvested. Each growth stage is associated with different colours on the simulation interface at different times of the simulated crop year (Figure 10.7).

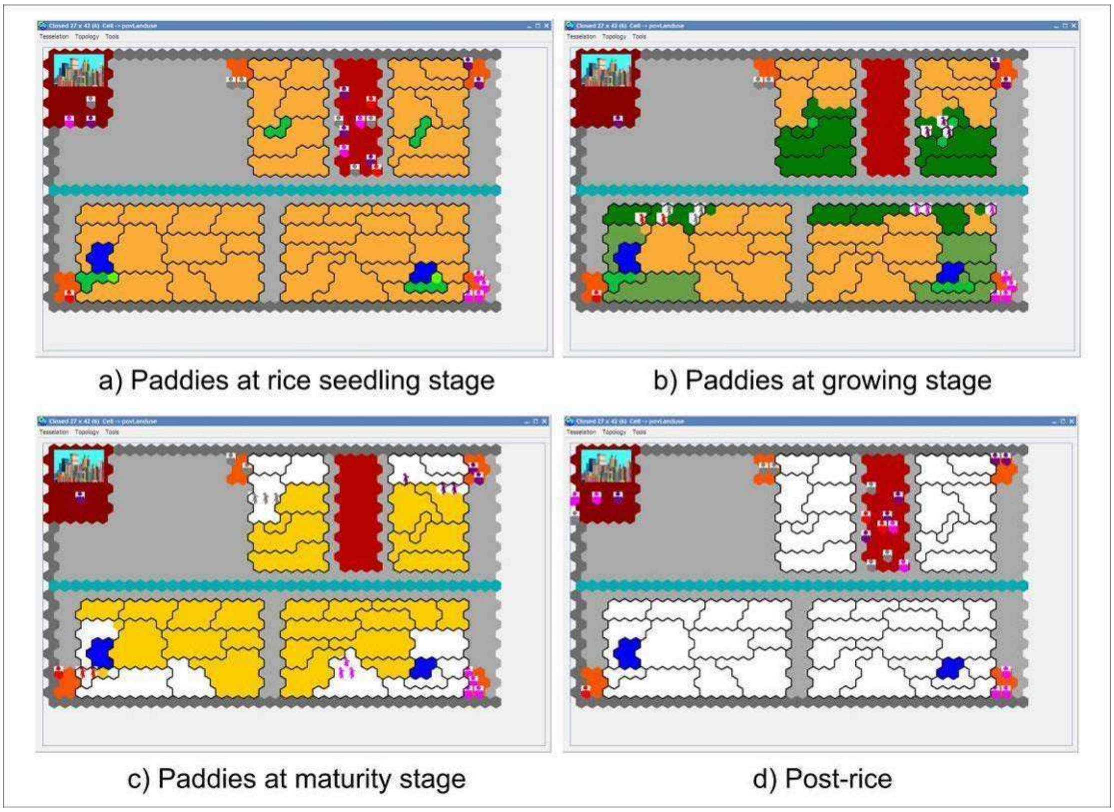


Figure 10.7 Display of paddy fields on the BMM interface during simulation of a rice cropping year.

10.2.3. Details

The last part of the ODD protocol aims to provide enough details so that the model can be re-produced from scratch. The details are grouped into three sections: initialization, model input, and sub-models.

10.2.3.1. Initialization

As I experienced some difficulty in meeting the model's purpose when introducing the 11 households and their actual means of production (participants were just concerned with the household initialized in their situation, looking for perfect similarities between the representation of their farm and their actual conditions), a simplified initialization to have only four virtual farms was designed. Two households (A1 and A2) represented type A farmers (the majority of farming households found in the study area) while types B and C were represented by households B and C respectively (see Figure 10.6 and Table 10.2). Beyond the farm size, the land/labour ratio to represent each main farm type according to the results of my on-farm survey and farmer typology was taken into account. The characteristics of each individual member were chosen to represent the heterogeneity of family members living in a household (Table 10.3). The initial water level in ponds was set to 0 cm.

Table 10.2 Characteristics of simulated households at initialization.

Household	*Farm size (ha)*	*Pond volume (m^3)*	*Family labour*			*Family dependent*
			Farmer	*Seasonal migrant*	*More-permanent migrant*	
A1	3.3	no pond	3	1	0	2
A2	3.3	no pond	3	0	1	2
B	6.5	7,200	2	0	0	1
C	6.5	4,800	2	1	0	4

Table 10.3 Characteristics of individuals from each household at initialization.

Household	*Name*	*Gender*	*Age*	*Marital status*	*Migration experience*
A1	M1-1	Male	55	Married	Yes
	M2-1	Female	55	Married	No
	M3-1	Female	30	Married	Yes
	M4-1	Male	25	Single	Yes
	M5-1	Female	10	Single	No
	M6-1	Male	8	Single	No
A2	M1-2	Male	55	Married	Yes
	M2-2	Female	52	Married	Yes
	M3-2	Female	32	Married	Yes
	M4-2	Male	29	Married	Yes
	M5-2	Female	10	Single	No
	M6-2	Female	6	Single	No
B	M1-3	Male	50	Married	Yes
	M2-3	Female	45	Married	No
	M3-3	Male	5	Single	No
C	M1-4	Male	50	Married	No
	M2-4	Female	45	Married	No
	M3-4	Male	30	Married	Yes
	M4-4	Female	14	Single	No
	M5-4	Male	12	Single	No
	M6-4	Male	5	Single	No
	M7-4	Female	2	Single	No

10.2.3.2. Input

Daily rainfall and potential evapotranspiration (PET) data used in the model to vary the climatic conditions affecting agents' decisions to establish rice nurseries, transplant and harvest, were obtained from the regional meteorological centre located in Ubon Ratchathani province. The same set of 5 years (1991-1995) was used for all simulation experiments. This set was selected because they are the most recent successive 5 years with complete daily rainfall and PET data. Figure 10.8 shows the accumulation of daily water balance each year determined by daily rainfall subtracted by daily PET. This daily water balance inputs indicate water availability retained in farm ponds. The price of rice was set based on information obtained from the Thai Rice Mills Association (Table 10.1).

10.2.3.3. Sub-models

The sub-models correspond to the key activities practiced by local farmers during the rice production cycle. In the BMM model, once the selection of rice varieties to be grown has been made, the cycle starts and ends with rice post-harvest activity including updating Household and Member variables and labour migration.

At the beginning of a simulation run, rice varieties are selected. Depending on land per labour ratio, either a single or two rice varieties are produced. If the ratio is lower than 2 ha, only KDML105 variety is grown. Otherwise, two rice varieties (RD6 and KDML105) are planted. However, this ratio may change over time as family members update their labour status every year. The area planted to varieties for self-consumption depends on the needs of all household members.

Nursery establishment

The location of nurseries is set such that, as in the reality, it is neither far from the house nor from the pond (when it exists); higher places are better for water control. When there is no pond, the nursery is located in the middle of the farm.

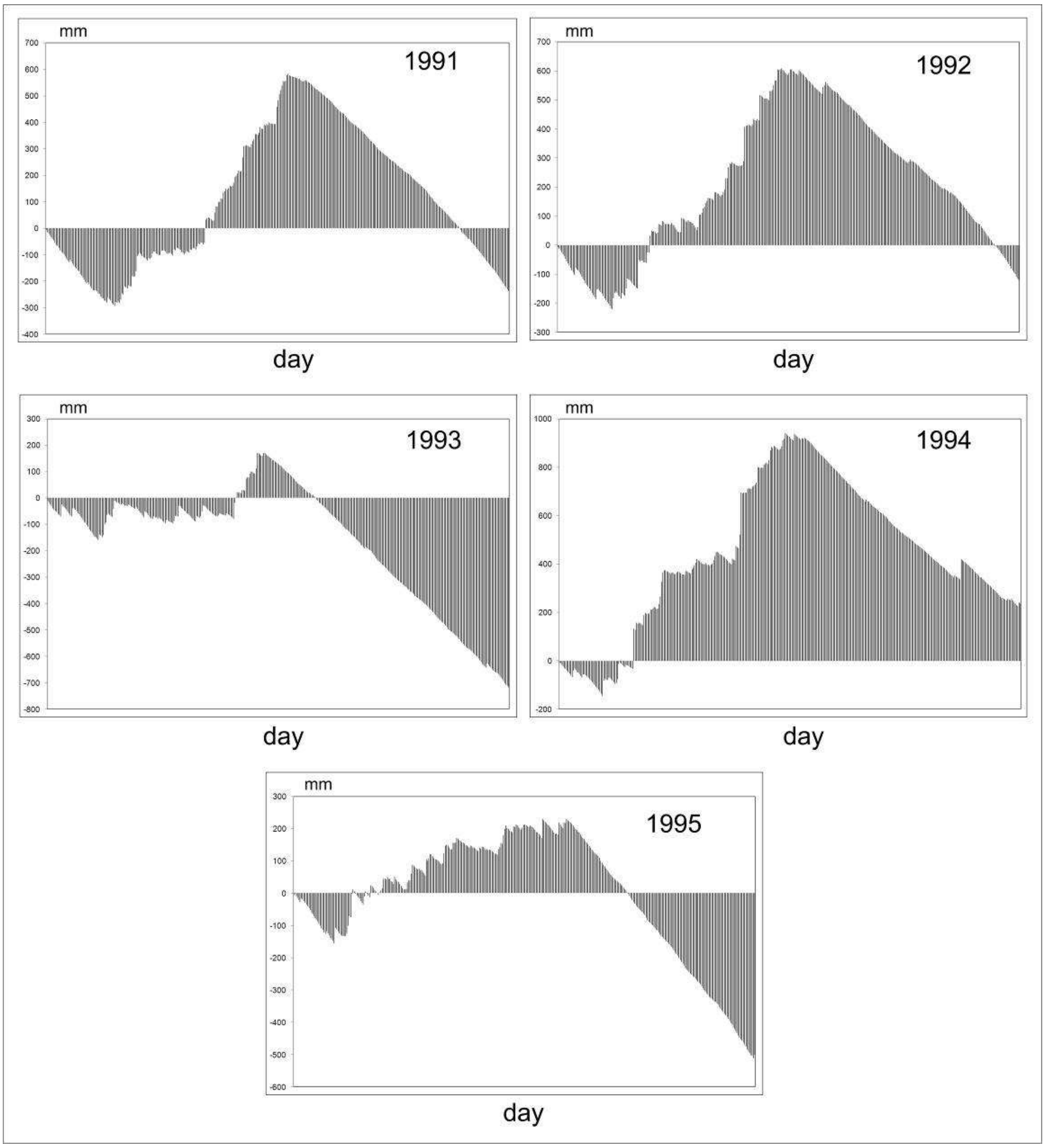


Figure 10.8 Accumulation of daily water balance input (mm) for water availability in farm ponds used in the BMM model.

The annual RLR production cycle begins in the second week of May, after the Royal ploughing ceremony held in Bangkok. From that date on, if the quantity of daily rainfall is higher than 30 mm, a nursery is established (Table 10.1). If the quantity of daily rainfall is lower than this threshold, water from the pond can be used for nursery establishment (80 m^3/ha), provided the water level is above 10% of the pond's depth (Figure 10.9). This activity takes only one day, and must be performed before the 3rd week of July (limit date for nursery bed) to ensure that rice being produced has enough time to accumulate biomass needed for the target yield. This activity is visualized on the simulation interface as light and dark green cells for RD6 and KDML105 varieties respectively (Figure 10.7a).

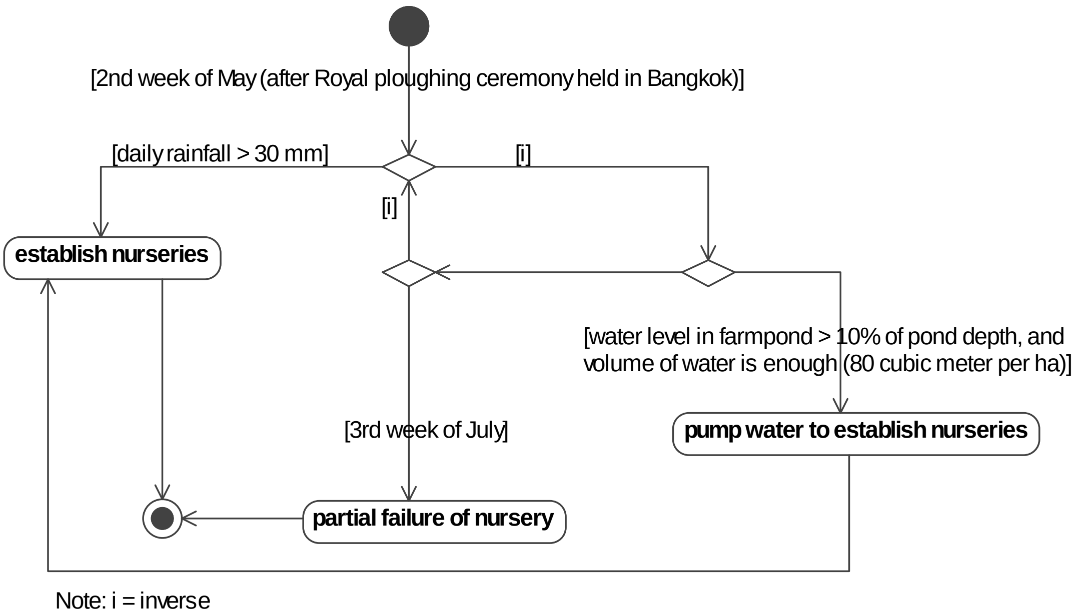
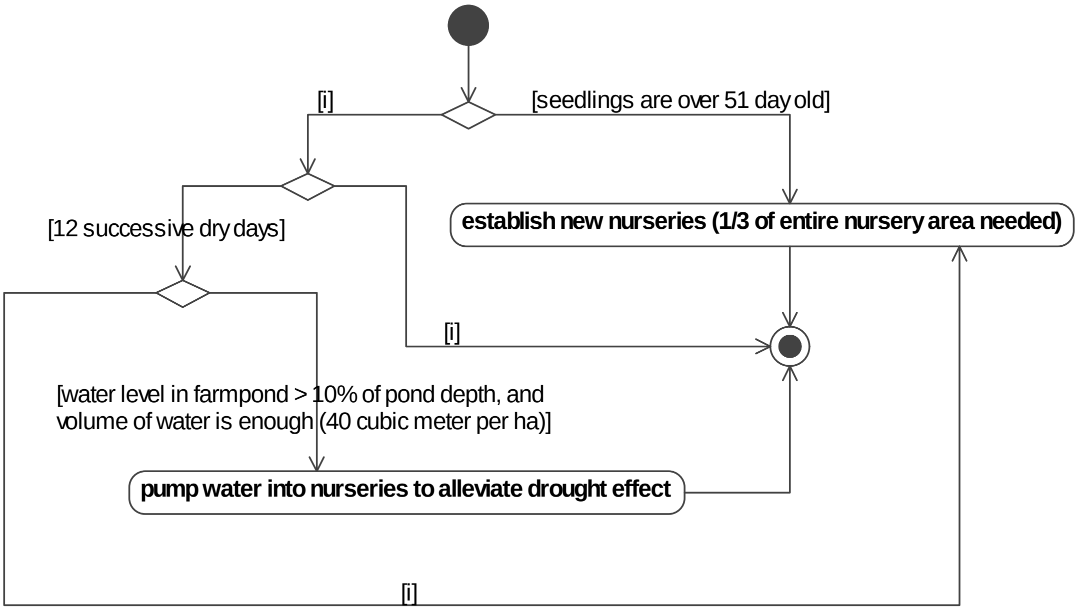


Figure 10.9 Algorithm for the establishment of a rice nursery bed in a UML activity diagram.

Irrigation water requirement for the maintenance of a nursery was defined through two thresholds: a daily rainfall threshold to define a dry day, and a number of successive dry days (12) needed to cause water stress in rice seedlings (Table 10.1). A water stress triggers a household to operate water pumping (40 m^3/ha). The seedlings in nurseries require 30 days to be ready for transplanting. Seedlings may become too old (over 51 days) for transplanting when a long dry spell occurs. Participating farmers said that water from the pond could only be used during the nursery phase, and not for transplanting. In case of water stress during the nursery stage or too long a period before transplanting, a 2nd nursery establishment needed to be established (Figure 10.10). According to the participants' suggestion, the algorithm takes into account when a 2nd nursery is needed, 1/3 of the whole nursery area will be resown because local farmers have never experienced a complete nursery failure.



Note: i = inverse

Figure 10.10 Algorithm for the maintenance of a rice nursery in a UML activity diagram.

Transplanting

Once rice seedlings are 30 days old and ready for transplanting, Rice entity sends a message to the household agent who checks whether or not the daily climatic conditions are suitable for transplanting (daily rainfall higher than 20 mm). The last date for transplanting was set to September 15; after that date the duration of the RLR vegetative phase would be too short to achieve satisfactory yields. In case this situation could not be avoided, some paddies would remain without rice. Once a household starts transplanting, its seasonal migrant members return home to take part in this activity. Additionally, a household can compute if additional workers are needed to be able to complete transplanting on time. Once a household has completed transplanting, no more rice activity will be done until November. Thus, farmers belonging to such households are located in the village area, ready to be hired by other households who have not completed transplanting yet (Figure 10.12).

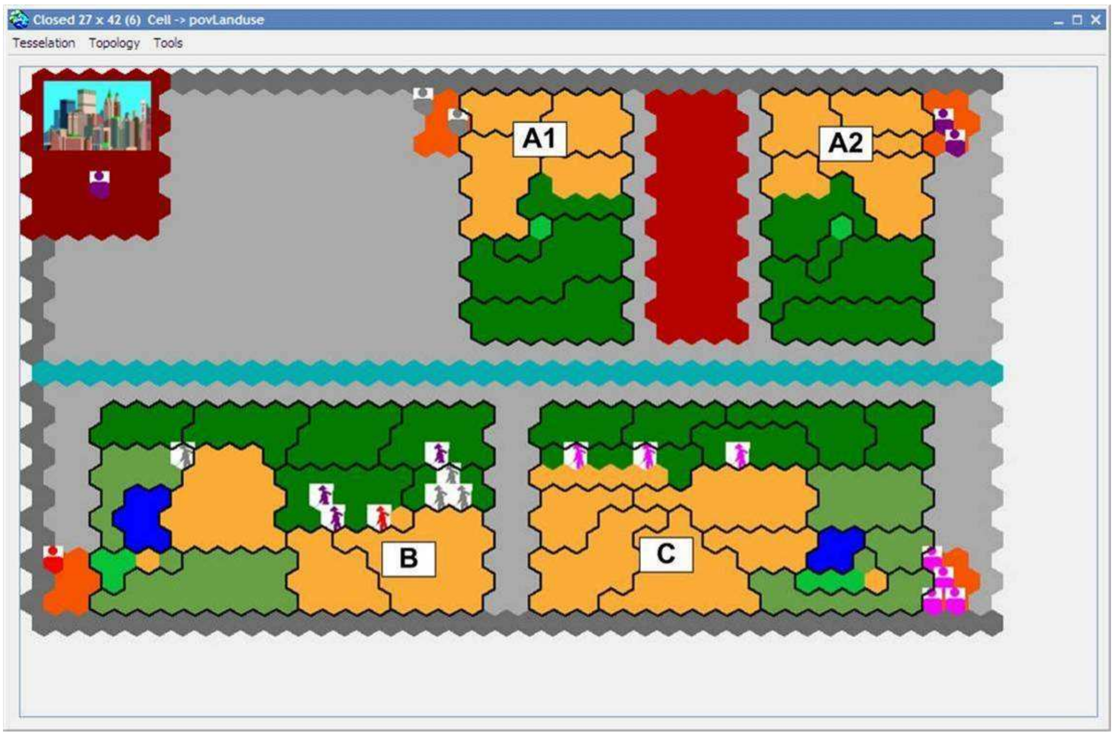


Figure 10.11 Members of household A1 and A2 being hired by household B during transplanting of KDML105 variety on the BMM model interface.

Participants were requested to transplant the RD6 variety first if it was produced. The transplanting of the RD6 start from the upper paddies downwards to the lower ones and its paddies has to be close to a house (or temporary storage hut). Because this RD6 rice variety is harvested earlier, the KDML105, which is growing, must not block the path to deliver RD6 paddy back to the storage hut.

The KDML105 variety is transplanted from lower paddies upwards to upper ones to ensure enough water for this farm gate rice. Water is collected at lower paddies and usually increases rapidly to upper paddies in August when rainfall is high and the water table is rising close to the ground. The detail of transplanting activity algorithm is provided in appendix 11.

Harvesting

Farmers return to the paddies to harvest at fixed dates defined in table 10.1. These dates correspond to the harvest time of these photo-sensitive late-maturing rice varieties. For the RD6 variety, the harvest time is set to the 10th of November and 10 days later for the KDML105 variety. In the BMM model, harvesting stops if the daily rainfall is more than 10 mm. Farmers will let the rice dry for one day after a wet day before restarting the harvest. The number of days it takes to complete the harvest is important in determining paddy quality, resulting in different prices that affect household income generated from KDML105 sales, which in turn influences migration decisions. Hiring labour could therefore be considered as a necessary practice for all farms to accelerate harvesting, so that this activity can be completed before the 1st of December to ensure the highest paddy quality (Figure 10.13). The recruitment of hired labour is often competitive in this period, resulting in a higher daily wage than during transplanting (see Table 10.1).

Participants requested rice to be harvested in the model from upper paddies towards lower ones. This practice is carried out in reality to avoid poor paddy quality because of high moisture. While rice is harvested, paddies will gradually dry out from upper to lower areas. The detail of harvesting activity algorithm is provided in appendix 12.

Labour migration

Once rice harvest is completed, two key operations are made in sequence. First, households update their household net income and members update their age, and migration experience. Then household members can decide whether or not to migrate. The household income is generated from rice sales and wages earned during rice production. The farm expenses are calculated based on farm inputs used. This household income will be updated. The annual household net income is computed as follows: (income from rice sales + wage received) – (farm inputs cost + labour cost + household expenditures). The level of updated household net income affects the selection of migratory patterns decided by members in the household.

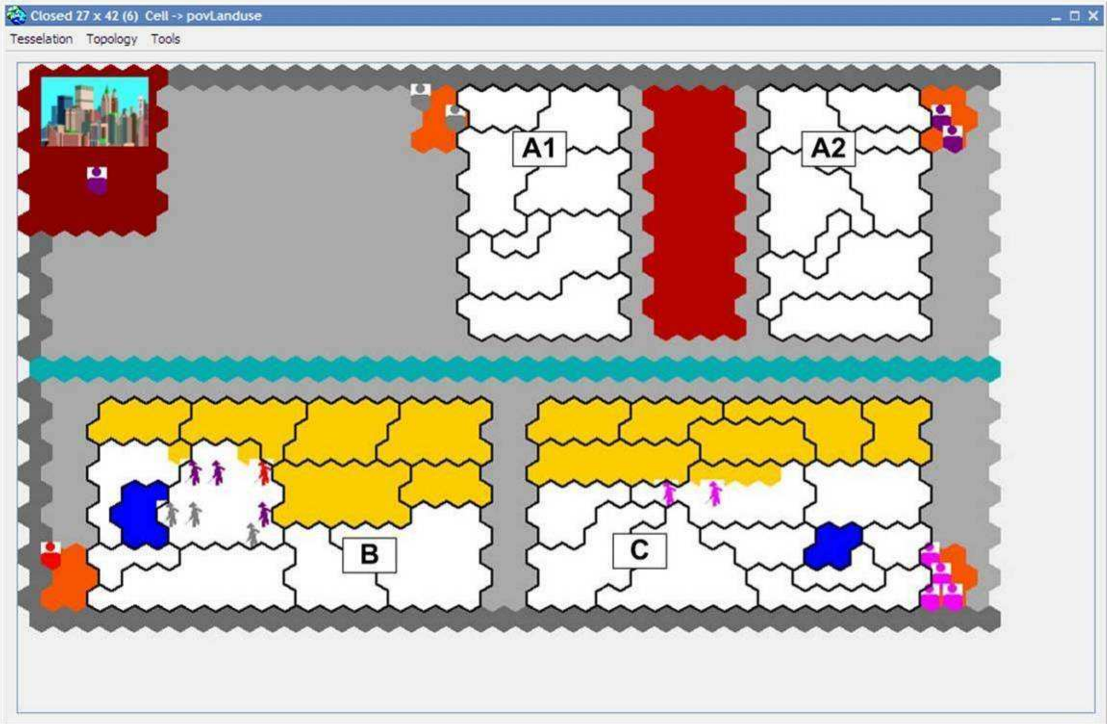


Figure 10.12 Members of household A1 and A2 being hired by household B during harvesting of KDML105 variety on the BMM model interface.

The migration decision involves multi-level factors from individual to village levels. Individual characteristics of members are considered as well as their household's social and economic status to determine whether they migrate during the dry season (seasonal migrant), migrate to the city without returning home to produce rice (more-permanent migrant) or do not migrate (Figure 10.13). An important social constraint is the presence of the elderly or/and children (dependant) who need to be looked after by an adult member. During the participatory simulation workshops, we could not reach an agreement about the minimum amount of annual net income needed for farmers to stay at home. This criterion is clearly different among the participating farmers. As a result, I decided to use the average annual net income for Northeast Thailand (20,000 baht per household) defined by the National Statistical Office (NSO) in 2007. At the end of a simulation, migrants will move to the city. However, household B did not have any migrants because two of its workers (45 and 50 year old respectively) were too old to migrate while the other one was only a 5 year old.

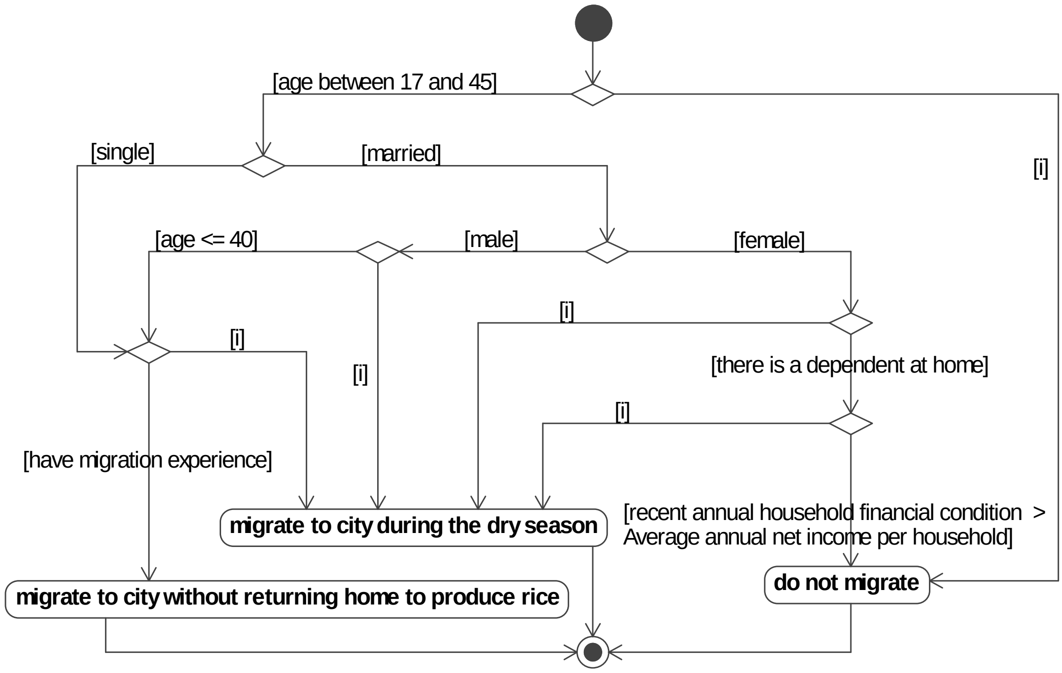


Figure 10.13 Algorithm representing individual decision to migrate or not in a UML activity diagram.

10.3. Calibration, Verification and Validation of the BMM model

Calibration is any parameter's value used to adjust the model's outputs in correspondence to the expected values. This process is similar to adjusting a measuring instrument using a calibration standard. After the model has been constructed, one begins the model verification process of checking that it is correct (Gilbert, 2008). The verification process investigates that the simulation program implemented in an operational model correctly represents its conceptual model, and ensures that the model satisfies what it is designed to do (Banks, 1998; Ferber, 1999). Simply, model verification deals with building the model right (Balci, 1998).

Once an ABM model has been developed, it is essential to check its validity. Validation is a determinant of whether the conceptual model can be substituted for the real system for the purpose of experimentation (Banks, 1998). Model validation deals with building a right model (Balci, 1998). However, both theory and practices of validation are complicated and controversial. The issues are related to the various objectives purported by modellers, which imply different criteria for validation and the insufficiency of social empirical data, which is usually hard to quantifiably acquire to allow systematic validation (Troitzsch, 2004). It is important to recognize that my ability to validate a model directly depends on how much we already know about the system under study (Deaton and Winebrake, 1999). The calibration, verification and validation are carried out with several techniques to assess credibility at each stage of the life cycle of a simulation study (Balci, 1998). These processes are often iteratively carried out once the programmed model is implemented.

10.3.1. BMM model Calibration and Verification

Many models are difficult to verify because they are often compounded by random number generators resulting in different outputs in every run. Only the distribution of results can be anticipated by the theory (Gilbert et al., 1999). But that is not true in this case because the BMM model is purely deterministic. Therefore, the outputs of this model can be determined based on its initial inputs of selected parameters. Several verification techniques were used to accomplish the verification purpose including debugging[17], cause-effect graphing[18], and functional testing[19] (Balci, 1998).

During the BMM model's co-construction with participating RLR farmers, the 'debugging' was also consistently carried out. The cause-effect graphing to verify water balance in ponding and water storage tanks of the BMM model was also conducted. During the test, only the complex hydroclimatic processes were executed. However, various difficulties were discovered. In particular, many values belonging to unidentified parameters were used. Such difficulties impeded the model verification process. Consequently, I decided to simplify the hydrological processes (see details in chapter 8). Instead of underground water losses, the water outflow caused by the soil-plant system (10 mm per day) was a calibrated value used to balance water availability in the ponding tank to sufficiently represent the water dynamics based on farmers' perceptions (see in Table 10.1).

[17] Debugging is an iterative process whose purpose it is to uncover errors and misconceptions causing the model's failure and to define and carry out the model changes that correct the errors.

[18] Cause-effect graphing assists model correctness assessment by addressing the question of what causes what in the model representation.

[19] Functional testing is used to assess the accuracy of model input-output transformation. It is virtually impossible to test all input-output transformation paths for a complex simulation model. Therefore, this technique aims to increase my confidence in model mode input-output transformation accuracy as much as possible.

Besides that, functional testing was carried out. A spreadsheet was produced and used to check: (i) the day that RLR establishment begins, (ii) the occurrence of water stress which triggers the irrigation function in the BMM model, and (iii) the day that run-off is operated (see Table 10.4). Under the same initial input values and thresholds, the simulated results of the BMM model were compared to the outputs generated by the spreadsheet. It was found that the BMM simulation provided the same outputs than those of the spreadsheet.

10.3.2. BMM model Validation

Similar techniques to model verification were used to achieve this task. Debugging and functional testing has often been conducted in the laboratory at the same time as the BMM model verification. However, in this ComMod experiment, the BMM model was commonly validated throughout its co-construction with participating farmers. Additionally, two techniques were used: the face validation[20] and turing test[21] (Balci, 1998).

Thanks to the principles of these techniques, the participating farmers are RLR grower experts who are knowledgeable about the RLR ecosystem under study. They observed the BMM simulations and analyzed the outcomes based on their mental models derived from their indigenous knowledge and experience. According to the iterative continuous loops of this collaborative modelling process, less differentiation between the BMM model and participants' mental models was identified. Likewise, the responses from participating farmers provided valuable feedback for correcting model representation. The BMM algorithms were then improved accordingly and the validity of model was gradually increased (see Table 10.5).

[20] Face validation is often carried out within a team of members and people knowledgeable about the system under study. The objective is to compare model and system behaviours under identical input conditions and judge if the model and its results are reasonable.

[21] Turing test is based on the expert knowledge of the system under study. Without identifying the simulations prior to its run, the experts are asked to differentiate between their mental model and simulation model.

Table 10.4 A spreadsheet produced to generate the outputs of 1986 to verify the BMM simulation outputs under the same value of parameters and thresholds, with the 18th of May highlighted for the beginning date of RLR nursery establishment.

Parameters' value input		day	1986							
			Accumulated water level in farm ponds (mm)	Accumulated water volume in farm ponds (m3)	Accumulated water volume in farm ponds is enough to build nursery? (m3)	Accumulated water volume in farm ponds is enough to mitigate drought? (m3)	Daily rainfall (mm) with highlight date to establish nursery	Water level (mm) in ponding tanks (paddies)	Water stress happens?	Run-off in paddies is operated?
Initial water level in farm ponds		Apr-01	118.30	189.28	NO	YES	23.40	108.30	NO	NO
100	mm	Apr-02	112.60	180.16	NO	YES	0.00	102.60	NO	NO
		Apr-03	107.00	171.20	NO	YES	0.00	97.00	NO	NO
Pond size		Apr-04	101.60	162.56	NO	YES	0.00	91.60	NO	NO
1600	m2	Apr-05	95.40	152.64	NO	NO	1.00	85.40	NO	NO
		Apr-06	87.60	140.16	NO	NO	0.00	77.60	NO	NO
Farm size		Apr-07	80.80	129.28	NO	NO	0.00	70.80	NO	NO
40	rai (0.16 ha)	Apr-08	76.20	121.92	NO	NO	0.00	66.20	NO	NO
		Apr-09	70.10	112.16	NO	NO	0.00	60.10	NO	NO
Nursery size		Apr-10	63.71	101.94	NO	NO	0.01	53.71	NO	NO
4	nagn (0.04 ha)	Apr-11	57.21	91.54	NO	NO	0.00	47.21	NO	NO
		Apr-12	51.01	81.62	NO	NO	1.50	41.01	NO	NO
Water volume needed to establish		Apr-13	46.21	73.94	NO	NO	0.00	36.21	NO	NO
320	m3	Apr-14	41.91	67.06	NO	NO	0.00	31.91	NO	NO
		Apr-15	34.91	55.86	NO	NO	0.00	24.91	NO	NO
Water volume needed to mitigate drought		Apr-16	30.61	48.98	NO	NO	0.00	20.61	NO	NO
160	m3	Apr-17	23.61	37.78	NO	NO	0.00	13.61	NO	NO
		Apr-18	17.81	28.50	NO	NO	0.00	7.81	NO	NO
Water staroge tank height (farm pond depth)		Apr-19	10.01	16.02	NO	NO	0.00	0.01	NO	NO
3000	mm	Apr-20	2.51	4.02	NO	NO	0.00	0.00	YES	NO
		Apr-21	0.00	0.00	NO	NO	0.00	0.00	YES	NO
Water to be kept in farm ponds		Apr-22	0.00	0.00	NO	NO	2.10	0.00	YES	NO
0	% of farm pond depth	Apr-23	0.00	0.00	NO	NO	0.01	0.00	YES	NO
		Apr-24	3.90	6.24	NO	NO	5.90	0.00	YES	NO
		Apr-25	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		Apr-26	5.20	8.32	NO	NO	11.90	0.00	YES	NO
		Apr-27	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		Apr-28	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		Apr-29	0.00	0.00	NO	NO	0.01	0.00	YES	NO
		Apr-30	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		May-01	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		May-02	0.00	0.00	NO	NO	0.90	0.00	YES	NO
		May-03	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		May-04	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		May-05	0.00	0.00	NO	NO	3.60	0.00	YES	NO
		May-06	0.00	0.00	NO	NO	0.00	0.00	YES	NO
		May-07	29.00	46.40	NO	NO	32.20	19.00	NO	NO
		May-08	61.80	98.88	NO	NO	35.70	51.80	NO	NO
		May-09	60.40	96.64	NO	NO	3.90	50.40	NO	NO
		May-10	54.70	87.52	NO	NO	0.00	44.70	NO	NO
Beginning of RLR nursery establishment		May-11	47.70	76.32	NO	NO	0.00	37.70	NO	NO
		May-12	40.80	65.28	NO	NO	0.00	30.80	NO	NO
		May-13	32.50	52.00	NO	NO	0.00	22.50	NO	NO
		May-14	24.30	38.88	NO	NO	0.00	14.30	NO	NO
		May-15	16.00	25.60	NO	NO	0.00	6.00	NO	NO
		May-16	28.20	45.12	NO	NO	19.10	18.20	NO	NO
		May-17	51.20	81.92	NO	NO	28.30	41.20	NO	NO
		May-18	95.00	152.00	NO	NO	50.30	85.00	NO	NO
		May-19	96.30	154.08	NO	NO	5.40	86.30	NO	NO
		May-20	101.50	162.40	NO	YES	10.30	91.50	NO	NO

Table 10.5 Feedback and parameter values from participating farmers used to validate algorithms of the BMM model.

Algorithm		*Feedback*	*Parameters and their values*
Crop establishment	RLR management	• Paddies with ponds: Nursery locates upper paddies near pond • Establishing nursery determined by accumulated daily rainfall, not measure soil moisture • Grow two varieties: - Glutinous rice (RD6): Transplant from upper paddies near house downwards to lower ones - Non-glutinous rice (KDML105): Transplant from lower paddies upwards to upper ones • Grow only one variety (KDML105): Transplant from lower towards upper paddies • Complete failure of nursery never happens • No water pumped from farm ponds for transplanting	• The ratio of rice nursery bed area to transplanted area is 1:40 • RLR transplanted area by young farmer: 0.16 ha/day/labour • RLR transplanted area by farmer older than 50 year old: 0.08 ha/day/labour • Pump water to establish a 0.04 ha RLR nursery: 80 cubic meters • Pump water to supply a 0.04 ha RLR nursery: 40 cubic meters • 1/3 of the whole nursery area will be resown if water stress occurs • Daily wage at RLR transplanting: 120 bath/labour
	Migration practices	• Migrant workers belonging to type A farming households return home when transplanting starts • Few farm workers migrate after transplanting	
Rice harvest and post-rice harvest	RLR management	• Stop harvesting and wait for a day if there is a heavy rainfall • Extra workers are not needed to harvest RD6 variety • Extra workers are hired to complete harvesting KDML105 variety as soon as possible to get high quality rice for high price	• RLR harvested area: 0.08 ha/day/labour • Daily wage at RLR harvesting: 150 bath/labour
	Migration practices		• Age of potential migrant: between 17 to 45 year old • Limited age to be a migrant worker for a male and married villager: older than 40 year old

Once the BMM model was validated by participating farmers to sufficiently represent their current situations, it was intended to be used for scenario exploration exercises. The use of the BMM model through the test of its sensitivity, field-based simulation and participatory analysis, and discovery of diverse scenarios in the laboratory is presented in the next chapter.

CHAPTER 11
EXPLORATORY SIMULATIONS
WITH THE BAN MAK MAI AGENT-BASED MODEL

According to the sequentiality of the modelling process (see details in chapter 6), after the design phase, simulations are run to make use of the model for knowledge discovery. The exploration of the dynamic behaviour of the model is usually firstly oriented towards a systematic investigation of the sensibility of the models to a set of key parameters. This first step allows pointing out parameters that drastically influence the dynamic behaviour of the model. Ultimately, it may give indications to narrow down the spectrum of scenarios interesting to be explored by simulation.

Scenarios are described as possible future alternatives that take into account the interactions of various heterogeneous components of a complex system (Wagener, Liu et al., 2006). Rather than relying on predictions of such alternatives, scenarios produced in a collaborative modelling process are purported to enable creative thinking to prepare stakeholders to face an uncertain future events (Schwartz, 1996). Scenarios simulated provide a dynamic view of the prospective events by exploring different trajectories of change (Means, Patrick et al., 2005). Two types of scenarios are often referred in the literature: explanatory and anticipatory scenarios. Explanatory scenarios are used to describe the future according to known processes of change and given extrapolations from the past. These are scenarios with no major interventions or paradigm shifts along their progression (McCarthy, Canziani et al., 2001). Explanatory scenarios were usually produced to examine future trends projecting forwards in time using trend experienced over some past period, and imagine upcoming change that significantly varies from the past (Hulse and Gregory, 2001). Anticipatory scenarios are based on different desired or feared visions of the future. They correspond to a specific future that is achievable only if certain events or actions take place (Godet and Roubelat, 1996).

In the context of companion modelling, “scenario” is straightforwardly understood as an operating mode for the simulation model, or more precisely a set of factors which are going to modify its operation: a certain stakeholder behaves differently, certain ecological dynamics are disturbed, certain variable of social or economic clamping is changed. Changes in how interactions are organised is also frequently envisages (new exchange systems, new negotiation protocols).

From a methodological point of view, the sensitivity analysis helps to detect specific characteristics, critical determinants and key parameters that drive the system under study. These elements are considered to formulate scenarios identified by model users. Once the scenarios are run, the detailed quantitative and/or qualitative information would subsequently be analyzed for impact assessment. Scenario analysis focusing on identifying the consequences of interactions among the boundary conditions, driving forces, and system components is a process of evaluating possible future events through the consideration of alternative possible outcomes and their implications (Wagener et al., 2006). Because unanticipated conditions have more chances to occur over a long period of time, long-term scenarios have more uncertainty than short-term scenarios. Besides, to eliminate some constrains, such as demographic change (see details in chapter 10), only 5 simulation years were run.

This chapter starts to use the BMM model for of the scenario exploration in field-based simulations and participatory analysis followed by laboratory-based simulations and analysis.

11.1. Field-based Simulations and Participatory Analysis

In general, scenario analysis is primarily a scientific effort, employing a variety of statistical and other analytical techniques to examine the scenarios. In my case, the baseline scenario was first presented to the local farmers. During the same workshop, they proposed alternative scenarios that were run on the spot, leading to extensive and intensive discussion among themselves and with the scientific team.

11.1.1. Scenario Identification

During the participatory simulation workshop organized in May 2008, two scenarios were identified by participating RLR farmers (see details in chapter 8). The first scenario was characterized by the presence of 30 cheap wage-earners from neighbouring countries (no labour constraint scenario). The second one was featured as no water constraint situation as a result of farm ponds always full of water.

11.1.2. Scenario Exploration and Participatory analysis

In the “no labour constraint” scenario, the simulation showed higher income differentials across farm types compared to the baseline scenario (see details of the baseline scenario in chapter 10). Income from rice sales of small farms was not significantly different, but they lost on-farm income received from large farms compared to the baseline scenario. In contrast, without labour constraints and despite higher labour costs, large farming households earned higher incomes from selling high quality paddy thanks to faster harvests. However, participating farmers argued that small farms may not lose on-farm income as much as it was shown by the simulated results. It was also argued that immigrant workers are not likely to be hired because they are not as meticulous as local rice farmers. Furthermore, local farmers prefer to hire labour within their kinship networks.

In the second scenario with guaranteed access to water, two large virtual farms could not complete the transplanting of its entire rice land when heavy rains came late, and by then some rice seedlings were too old to be used. This counterintuitive result (one may expect that water abundance would improve rice-growing performances) occurred because the pumping of water from a pond for transplanting activity was not possible in this model, accordingly to the insights of local farmers. Besides, due to a lack of knowledge regarding conditions where there is no water constraint, none of the participating farmers pointed out the usefulness of full water levels in the pond for transplanting.

Nevertheless, this result discloses an unobvious consequence of the synchronization of rice farming activities: when all local farmers start nursery at the same date (because all of them have access to irrigation water), they are all busy transplanting at the same time and consequently the availability of labour is temporarily lower than under desynchronized rice production, which in the simulation led to the problematic situation described above. Participating farmers did react to such exhibition by the model by arguing that the incomplete transplanting resulting in fallowed paddies is unlikely to happen in reality because rice farmers have practices not related to the use of water to avoid that by either establishing new nurseries, or buying healthy rice seedlings from neighbours. Participants were also aware of the risky decisions based on a water availability that is only made possible by erratic rainfall distribution. To clarify the point regarding extra nurseries, I modified the BMM model to integrate the risk of rice nursery failure (all rice seedlings become unusable, and a second rice nursery has to be established) into the model, and discussed the results with farmers. Once they observed the simulation, they disagreed with the total failure of the first nursery since it has never happened under their real circumstances. They proposed to let only a maximum share of 1/3 of the rice seedlings to die, or become worthless, for transplanting. The algorithm was modified in the model to take their comments into account. Both scenarios illustrate how water dynamics and labour availability are intertwined, resulting in varying amounts of household income, which is a key determinant of migration decision. To deepen the investigations about this mechanistic relationship, further explorations by simulation with the BMM model have been conducted back to the lab (on a scientific side only).

11.2. Laboratory-based Simulation and Analysis

11.2.1. Sensitivity Analysis of the BMM model

Sensitivity analysis is aimed at understanding the conditions under which the model yields the expected results, and estimating uncertainty particularly in integrated modelling studies (Gilbert, 2008). The principle behind is to systematically change the values of the initial conditions, parameters and inputs of the model by a small amount and rerun the simulation, observing differences in the outcomes (Balci, 1998). The purposes of sensitivity analysis are to: (i) test which parameters dominate a certain response to eliminate insensitive parameters to reduce model complexity and calibration burden, (ii) to test how well parameters are defined, or to test where additional effort should be placed to reduce uncertainty, and (iii) to test if parameters are sensitive in period where the processes they represent are assumed to dominate (Wagener et al., 2006). The results of sensitivity analysis are useful to narrow the range of parameters' value by selecting only the interesting ones to input in the BMM model for scenario exploration. This analysis is also often purposed to test "what if" scenarios. Likewise, it can be used to identify those input variables and parameters to the values of which the model behaviour is very sensitive. As a result, model validity can be enhanced by assuring that those values are specified with sufficient accuracy (Balci, 1998).

11.2.1.1. Selection of Parameters for the Sensitivity Analysis of the BMM model

It should be noted that even with only a few parameters, a sensitivity analysis can require an astronomical number of runs and thus to hold a practical strategy is challenging (Gilbert, 2008). As a result, the sensitivity of the BMM model was tested by limiting the range of values at some points where major changes in the simulation's behaviour were expected (e.g. crop establishment). Referring to the baseline scenario, I assumed that the successful rice crop establishment in the BMM simulations was likely to be sensitive mainly to four parameters: (i) the earliest starting date of RLR nursery establishment (not possible to establish a nursery bed prior to that date even when the conditions regarding water requirements are satisfied). In Thailand, the Royal Ploughing Day which is used to justify when the RLR production is supposed to start is, in fact, changed every year. I decided to test several dates in May (month of the Royal Ploughing Day), but also in April to evaluate the strategy "start as soon as possible"; (ii) the initial water level in farm ponds, tested with values 0 (default value used in the baseline scenario), 1, 2 and 3 m (full capacity); (iii) the daily rainfall threshold to enable starting RLR nursery establishment (when irrigation water is unavailable), tested with values 15, 20, 25, 30 (default value), 35 and 40 mm; and (iv) the daily rainfall threshold to start transplanting, tested with values 5, 10, 15, 20 (default value), 25 and 30 mm.

Because the main factor impacting the dynamics of the BMM model is undoubtedly the input of rainfall and PET patterns, the influence of these four parameters has been tested under: (i) 27 independent climatic years (Table 11.1) to investigate how these independent climatic conditions are affecting farm management across farm types, and (ii) 19 sets of successive 5 climatic years (Table 11.2) to investigate the effects on the migration patterns which evolve through time (each household member reconsiders its migration status by the end of every rice cropping season). The spatial and agent settings defined in the baseline scenario were reused (see details in chapter 10).

Table 11.1 Summary of 27 climatic years of accumulation of daily water input influencing water level in farm ponds.

Year	All seasons				Rainy season (May-September)
	Quantity at the end of each year (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Average (mm)
1966	0.00	481.68	1081.70	0.00	625.48
1967	0.00	0.00	68.20	0.00	0.00
1968	0.00	97.62	745.50	0.00	122.69
1969	0.00	0.00	433.20	0.00	113.37
1970	0.00	200.85	738.50	0.00	221.94
1971	0.00	0.00	405.50	0.00	111.01
1972	0.00	222.02	698.50	0.00	184.18
1973	0.00	0.00	315.30	0.00	0.00
1974	0.00	130.20	568.10	0.00	114.00
1975	0.00	98.39	500.70	0.00	39.88
1976	0.00	68.56	425.40	0.00	77.90
1977	0.00	0.00	202.10	0.00	0.00
1978	151.60	449.18	1020.10	0.00	341.75
1979	0.00	194.50	735.90	0.00	273.05
1980	0.00	215.05	598.20	0.00	183.05
1984	355.54	493.19	1087.38	0.00	308.70
1985	0.00	120.17	485.42	0.00	89.65
1986	0.00	137.86	579.85	0.00	47.63
1987	0.00	105.49	544.80	0.00	28.95
1988	0.00	0.00	252.71	0.00	100.51
1989	0.00	7.97	369.67	0.00	38.14
1990	40.24	245.05	641.53	0.00	153.81
1991	0.00	105.83	581.64	0.00	0.00
1992	0.00	199.67	607.47	0.00	141.53
1993	0.00	0.00	171.25	0.00	0.00
1994	235.82	432.97	939.80	0.00	386.15
1995	0.00	0.00	230.00	0.00	73.37

Note: Daily water input is computed on quantity of daily rainfall subtracted by quantity of daily potential evapotranspiration (PET).

To measure the impact of each combination of parameters under each climatic condition listed in tables 11.1 and 11.2, four indicators were defined: (i) number of nursery re-establishment, (ii) number of pumping water to establish nursery, (iii) number of pumping water to alleviate water stress, and (iv) percentage of paddy field without rice transplanted. In fact, as already mentioned, the event depicted by the last indicator never happens in actual circumstances because RLR farmers can buy healthy seedlings from their neighbours, but it was kept as such in the model to clearly display the impact of extreme drought on rice production.

Table 11.2 Summary of 19 sets of 5 successive climatic years of accumulation of daily water input influencing water level in farm ponds.

Years	All seasons				Rainy season (May-September)
	Quantity at the end of the first year (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Average (mm)
1966-1970	0.00	69.27	1081.70	0.00	171.56
1967-1971	0.00	26.00	745.50	0.00	98.01
1968-1972	0.00	55.77	745.50	0.00	119.16
1969-1973	0.00	61.20	738.50	0.00	117.71
1970-1974	0.00	78.56	738.50	0.00	105.46
1971-1975	0.00	56.51	698.50	0.00	81.45
1972-1976	0.00	30.98	698.50	0.00	34.87
1973-1977	0.00	68.83	1020.10	0.00	61.13
1974-1978	0.00	122.61	1020.10	0.00	113.02
1975-1979	0.00	136.75	1020.10	0.00	124.53
1976-1980	0.00	144.42	1020.10	0.00	141.45
1984-1988	355.54	121.83	1087.38	0.00	87.11
1985-1989	0.00	115.81	939.80	0.00	94.86
1986-1990	0.00	102.75	939.80	0.00	93.23
1987-1991	0.00	98.85	939.80	0.00	98.30
1988-1992	0.00	98.02	939.80	0.00	106.96
1989-1993	0.00	116.95	939.80	0.00	107.89
1990-1994	40.24	135.11	939.80	0.00	119.51
1991-1995	0.00	113.12	939.80	0.00	112.65

Note: Daily water input is computed on quantity of daily rainfall subtracted by quantity of daily potential evapotranspiration (PET).

11.2.1.2. Results of the Sensitivity Analysis of the BMM model

The beginning of RLR nursery establishment

"The beginning of RLR nursery establishment" parameter was set to range from 1st April to 31st May with intermediate values every 5 days: 351 simulations (13 different dates tested under each of the 27 available climatic years) were run. The overall results show that the beginning of RLR nursery establishment set in April triggered more nursery renewals than in May. This is particularly marked in case of households B and C (see Figure 11.1). However, the result was slightly different for households A1 and A2. Since these small holders are not equipped with farm pond in the baseline scenario, they have no opportunity to alleviate water stress by irrigating the nursery. However, fewer number of nursery re-establishment does not necessarily yield better outcome. As shown in Figure 11.2, the percentage of paddies without rice planted was higher when the beginning of RLR nursery establishment was set in May than in April. This could be a result of the shorter time to manage transplanting activity by household B who has labour constraint before reaching the last week for RLR transplanting.

With no water initially in farm ponds (as set in the baseline scenario), only very few simulations had irrigation water used by households B or C (4 occurrences only to establish nursery and 7 occurrences to alleviate water stress). Thus, I decided to run additional simulations to assess the influence of different initial water levels in farm ponds.

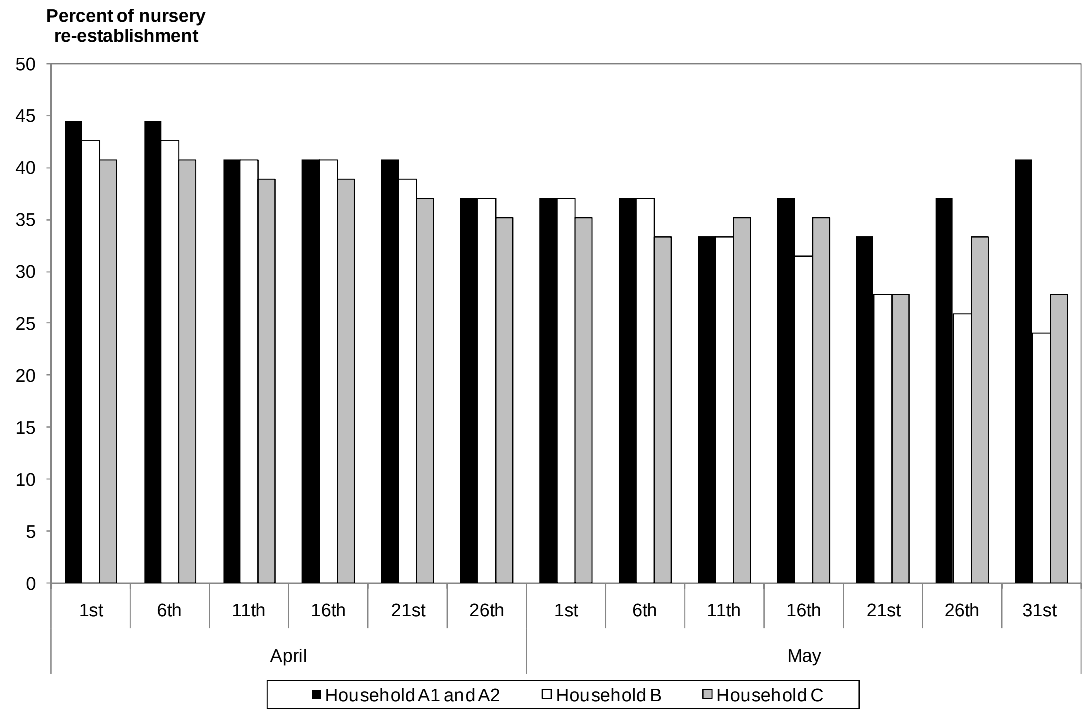


Figure 11.1 Influence of the earliest date to start nursery establishment on the accumulated number of nursery re-establishments

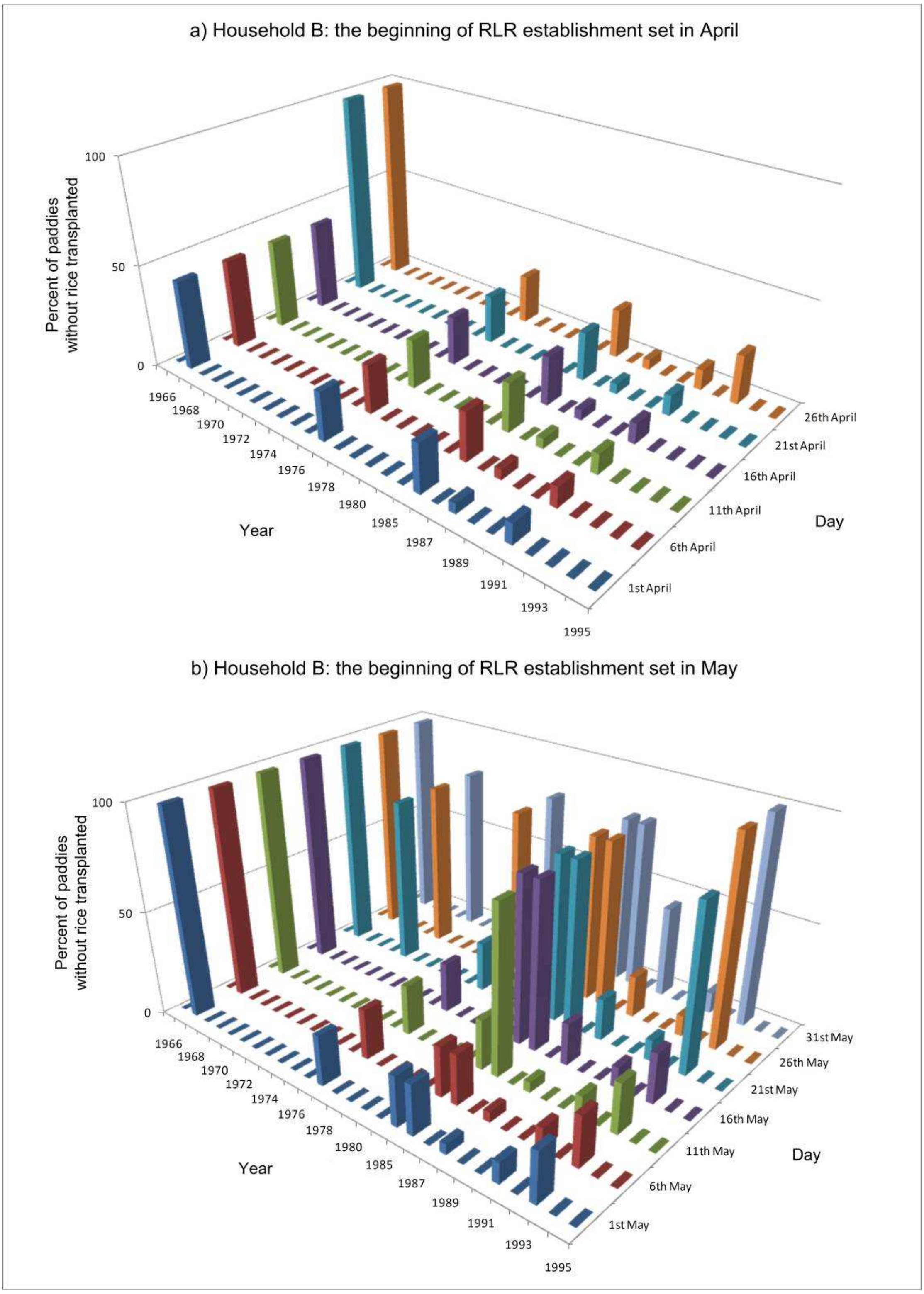


Figure 11.2 Influence of the earliest date to start nursery establishment on the percentage of paddy filed without rice transplanted (household B) under 27 climatic years.

Different initial water levels in farm ponds

Four values (0, 100, 200, and 300 cm) were set for the initial water level in farm ponds. After running 108 simulations to test these values under the 27 available climatic years, the result shows that water was equally more frequently used as soon as the initial water level was higher than 100 cm (see Figure 11.3). Because the farm pond belonging to household B is larger, it could store more water volume leading to more irrigation occurrences. When water is available (initial water level > 100 cm), logically there are fewer nursery re-establishments because water stress can be mitigated (Figure 11.4).

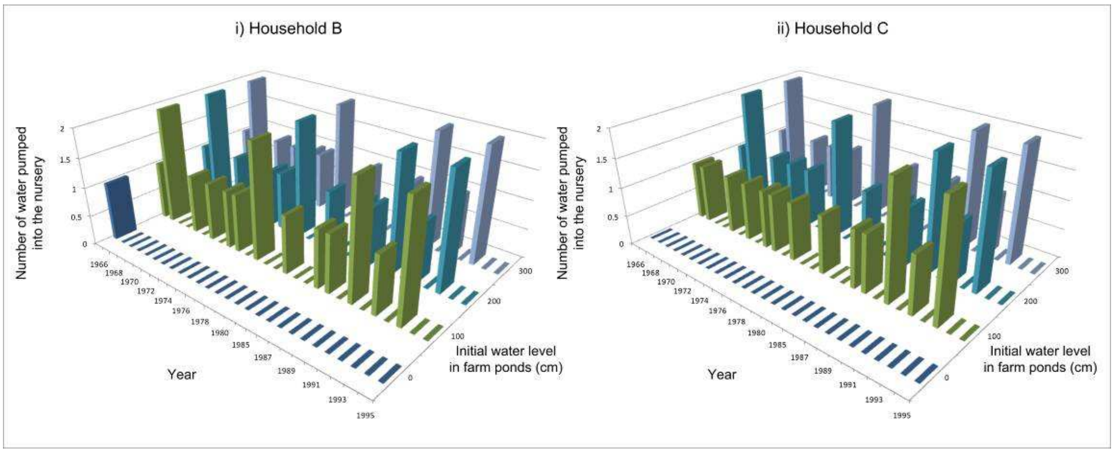


Figure 11.3 Influence of different initial water levels in farm ponds on the number of nursery bed irrigation occurrences.

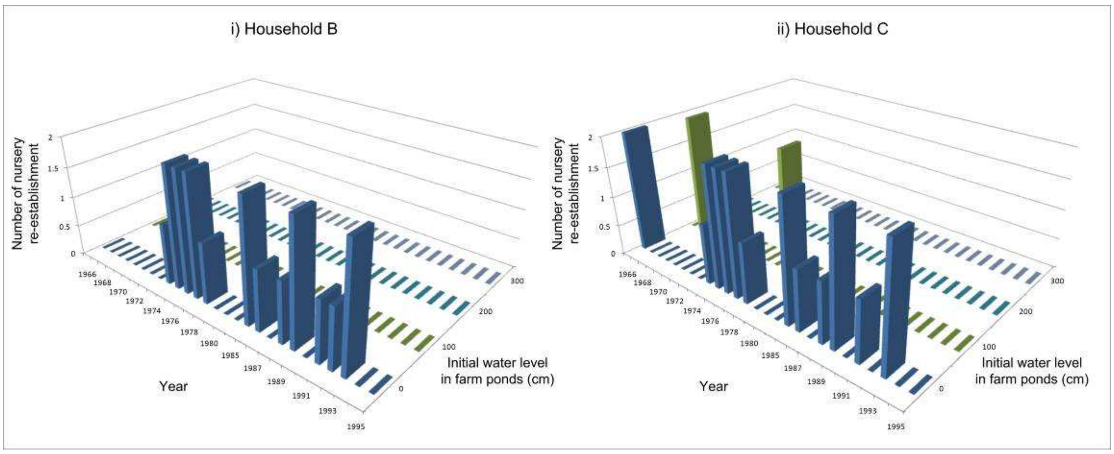


Figure 11.4 Influence of different initial water levels in farm ponds on the number of nursery re-establishment occurrences.

Daily rainfall threshold to initiate RLR nursery establishment

Six values were assigned to the threshold of daily rainfall needed to initiate RLR nursery establishment. The higher value of this parameter is likely to provide the fewer number of nursery re-establishments because sufficient water collected in ponding tanks of paddy fields could prevent the nursery failure caused by water stress (Figure 11.5). However, such important daily rainfalls are unlikely to happen during the early rainy season. This could lead to either the inadequate length of time for rice seedlings to be ready for transplanting, or delay transplanting as a result of the long dry spell. It, therefore, would affect the percentage of paddies with unsuccessful rice transplanted as shown in Figure 11.6.

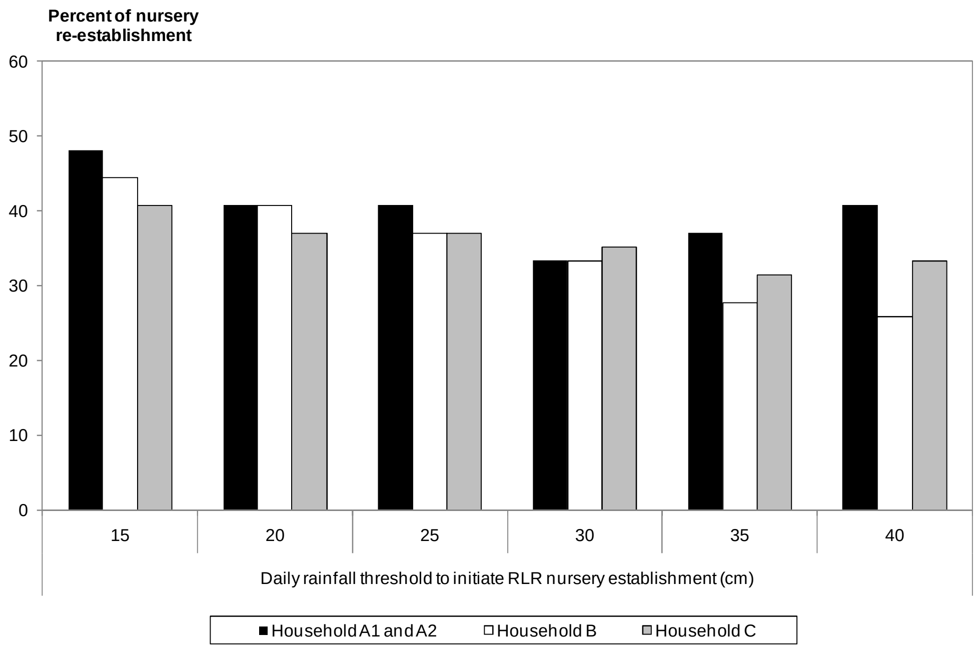


Figure 11.5 Influence of the daily rainfall threshold to initiate RLR nursery establishment on the Cumulated number of nursery re-establishments.

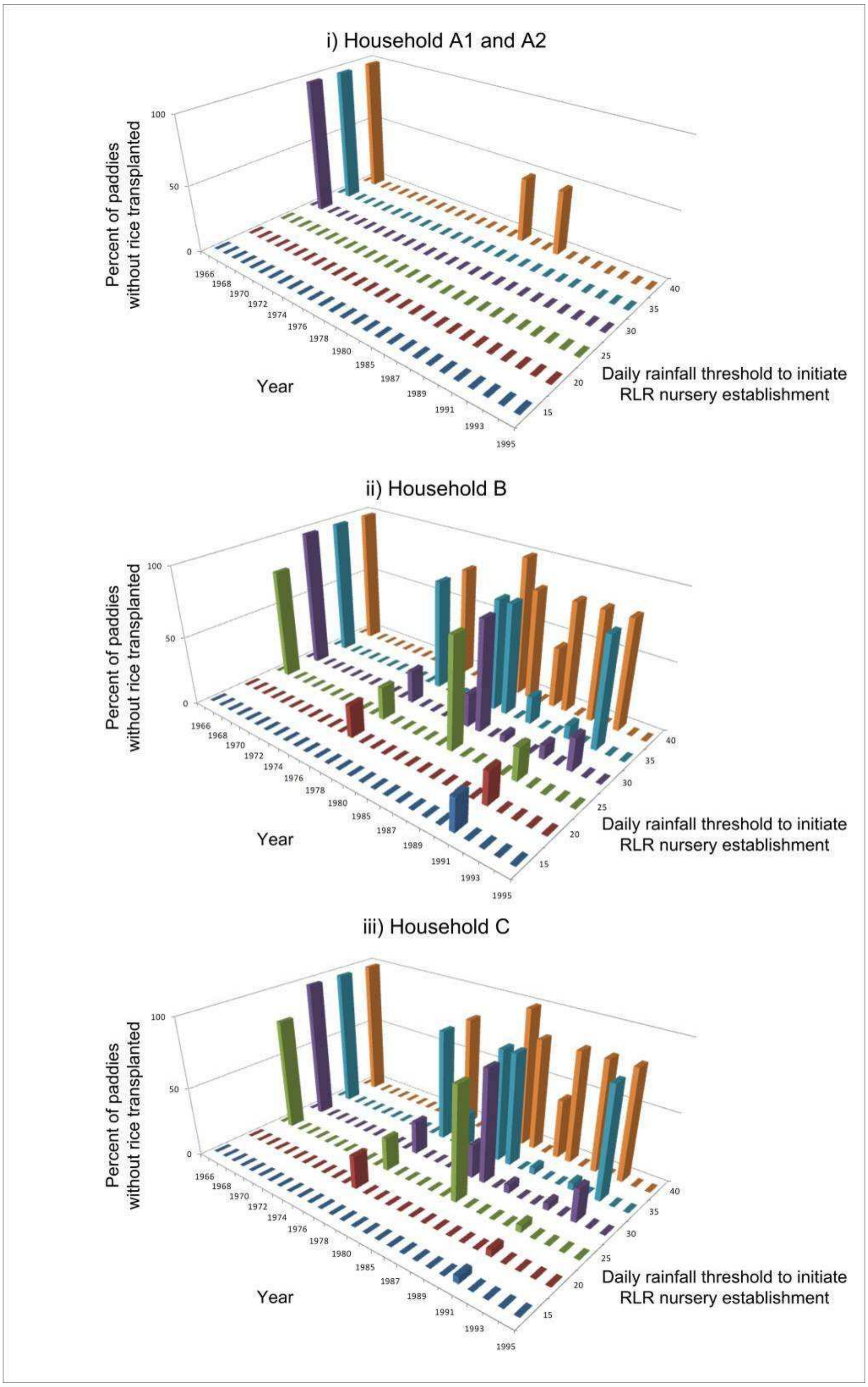


Figure 11.6 Influence of the daily rainfall threshold to initiate RLR nursery on the percentage of paddy filed without rice transplanted under different 27 climatic years.

Daily rainfall threshold to start transplanting

The daily rainfall threshold to start transplanting was varied with six values. Increasing values of this parameter cause little more occurrences of nursery re-establishment (Figure 11.7). This is because the delayed start of transplanting caused by long waiting for the daily rainfall to reach the threshold lead the rice seedlings ready to be transplanted (30 days old) for too long (more than 15 more days) in the nursery. However, this parameter is unable to trigger the complete (for the entire paddy fields) failure of rice transplanting (Figure 11.8).

To explain the slight differences (in years 1988 and 1991) between households B and C in the percentage of paddy without rice transplanted, the availability of farm workers has to be investigated. Because household B is the one with the most labour constraint (only two family members who are farm workers), it suffers more failures to complete transplanting than any other household whose land and labour ratio is lower and therefore is able to complete more transplanted paddies. This result leads us to deepen the exploration of the effects of interactions between water and labour availability on rice production of the households and on the migration patterns of their family members.

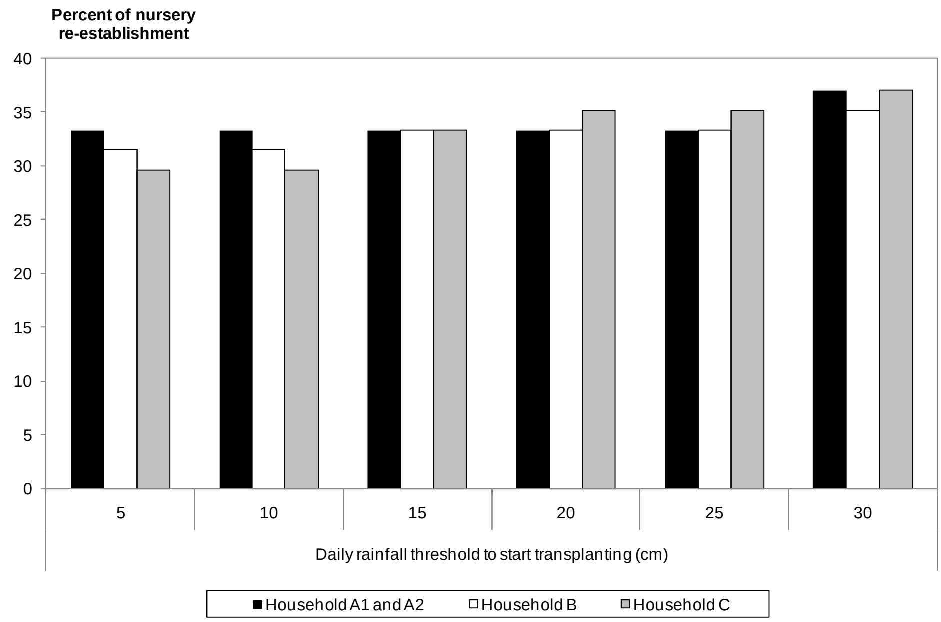


Figure 11.7 Influence of the daily rainfall threshold to start transplanting on the accumulated number of nursery re-establishment.

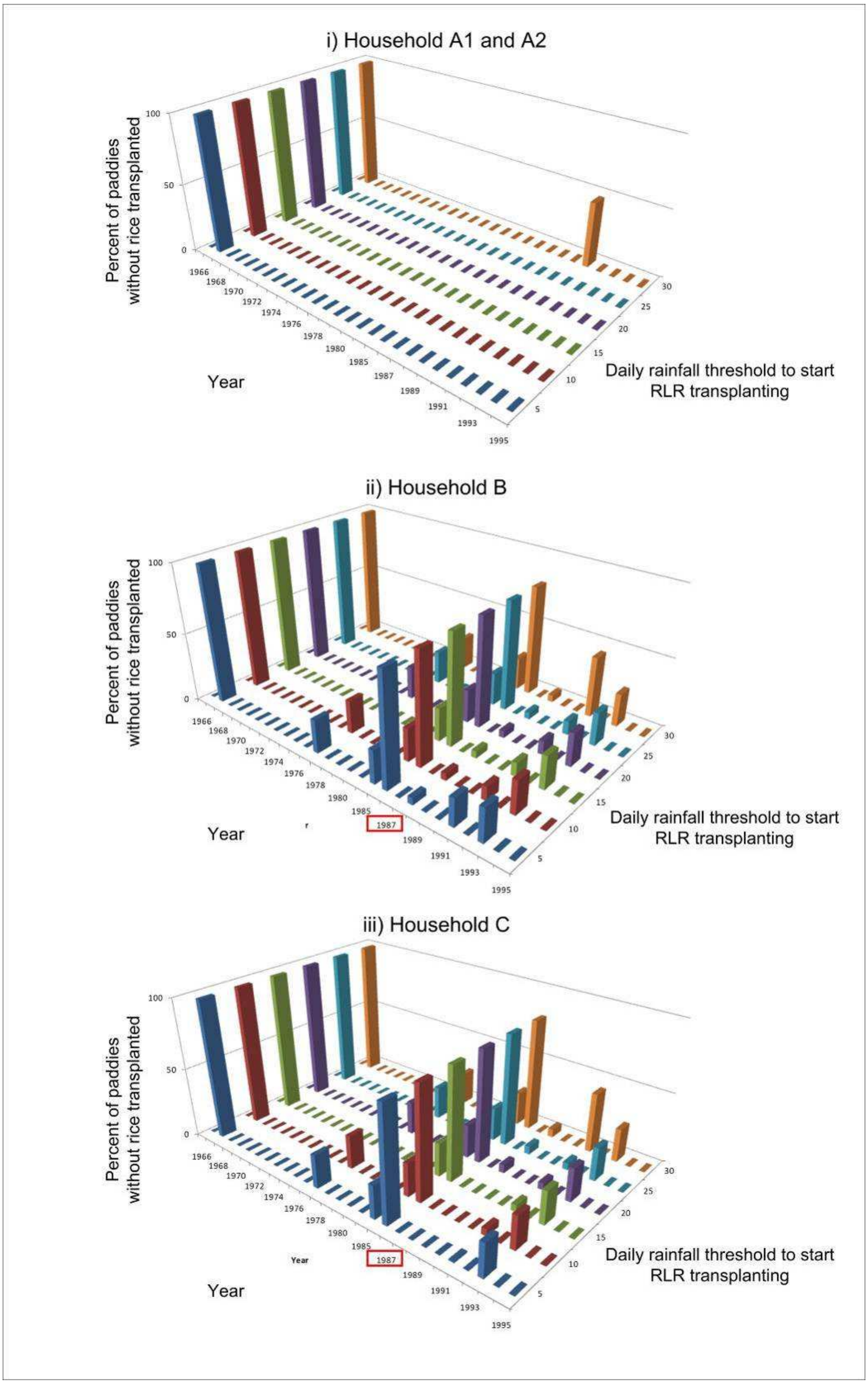


Figure 11.8 Influence of daily rainfall threshold to start transplanting on the percentage of paddy filed without rice transplanted under different 27 climatic years.

11.2.2. Exploration of Scenarios based on Water and Labour Availabilities

11.2.2.1. Scenario Identification

Nine scenarios were proposed to examine interactions between water and labour availability, as shown in Table 11.3.

Table 11.3 Coding of the 9 scenarios defined to explore the interactions between water availability and labour availability.

		Water availability (W)		
		No farm has farm pond (n)	Two large farms (B and C) have farm ponds (i)	All farms have farm ponds (a)
Labour availability (L)	No hired farm workers from outside the village (n)	WnLn	WiLn ☐	WaLn
	10 hired farm workers from outside the village (i)	WnLi	WiLi	WaLi
	20 hired farm workers from outside the village (a)	WnLa	WiLa	WaLa

Three levels of water and labour availability are defined as none (n), intermediate (i) and all (a) available. These 9 scenarios represents intermediate situations from an extreme case of water and labour limitation (WnLn) to an extreme case virtually without limitation of water and labour (WaLa). For water availability, the 2 farm ponds in all three scenarios *Wi* are the one assigned to households B and C in the baseline scenario. However, in all three scenarios *Wa*, a similar pond (0.16 ha with 3 m deep) is assigned to each household. In all scenarios with farm ponds, the initial water level in all farm ponds is set to 200 cm. This value is based on the result of the sensitivity analysis: there is no difference of water use once the initial water level in farm ponds is higher than 100 cm. Here, to ensure that water is adequately available over 5 successive years, 200 cm of initial water level in farm ponds was set.

For all the other parameters, the values are the same than in the baseline scenario (see chapter 10 for more details). Five indicators defined at the household level will be analyzed: (i) income generated from rice sales, (ii) labour cost to produce rice, (iii) wage received by family members who are hired by other households, (iv) number of seasonal migrants and (v) number of permanent migrants.

The duration of a simulation is set to 5 successive years are used so that the evolution of labour status of households' members can be investigated. To account for the climatic variability, the 19 sets of 5 successive years presented in table 11.2 have been run for all 9 scenarios.

11.2.2.2. Scenario Analysis

Income generated from rice sales

The result shows that the labour availability, in all three sets *Wn*, *Wi* and *Wa* scenarios, influences positively and significantly the household income generated from rice sales (Figure 11.9). This is because more farm workers can accelerate the rice harvest leading to high paddy quality and high price in the market.

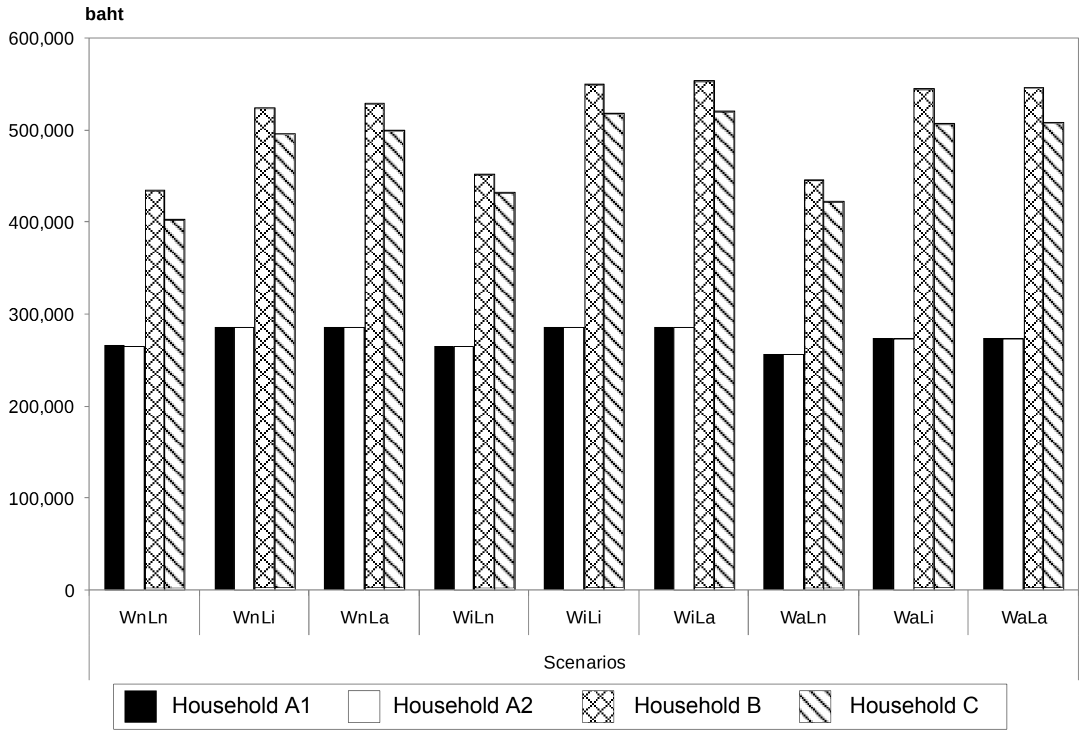


Figure 11.9 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household income from rice sales per household per scenario.

However, the most significant income differentiation is between "no additional labours from outside the village (*Ln*)" and "10 hired workers from outside

(*Li*)". There is no difference between *Li* and "20 hired workers from outside (*La*)" This is indicating that more workers may not provide different outcome once the all paddy was completely harvested before 1st December for high paddy quality. Even if such completeness was reached long before the date threshold, it would not increase the income generated from rice, but on the opposite more cash would be spent for hiring extra workers as shown in Figure 11.10.

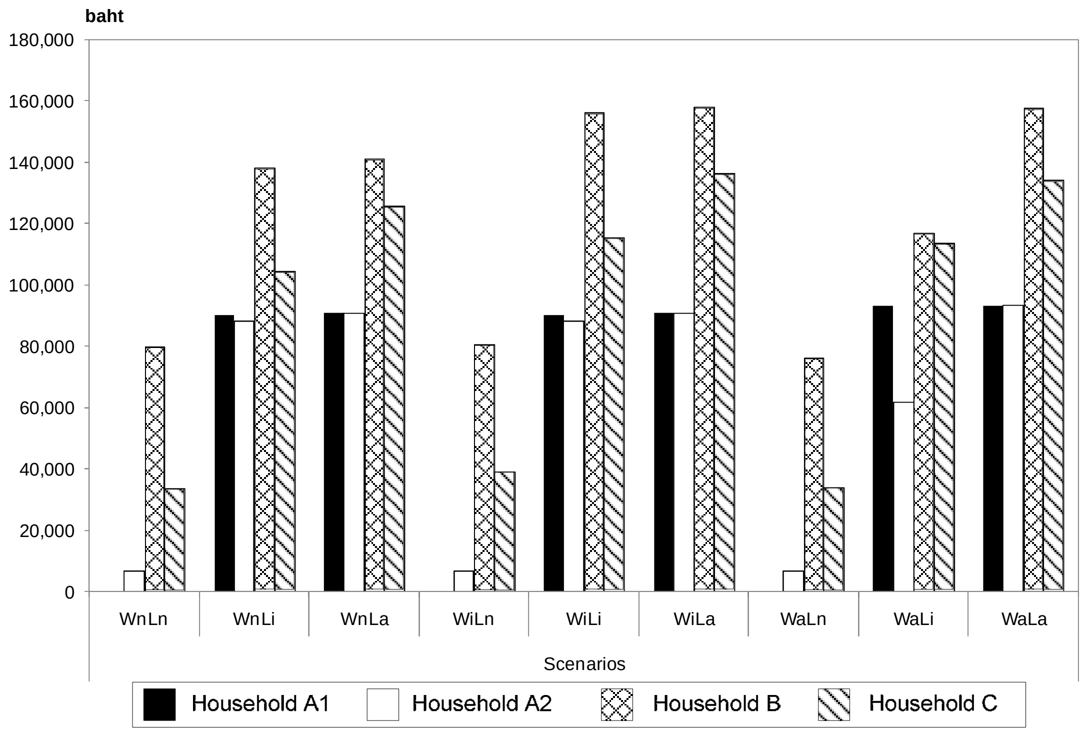


Figure 11.10 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household labour cost per household per scenario.

Hired wage received from on-farm employment to produce rice

In contrast to the household income, the differentiation of hired wage received by small holders A1 and A2 is significantly found between *Li* and *La*: the difference between *Li* and *Ln* appears insignificant (Figure 11.11). Based on Figure 11.9 and 11.11, it seems that the balance between household income and wage earned from on-farm employment needs careful considerations so that the household income from rice can be satisfying while the wage income of small holders is not decreased. Besides, based on this synthesis, such balance seems to be achievable.

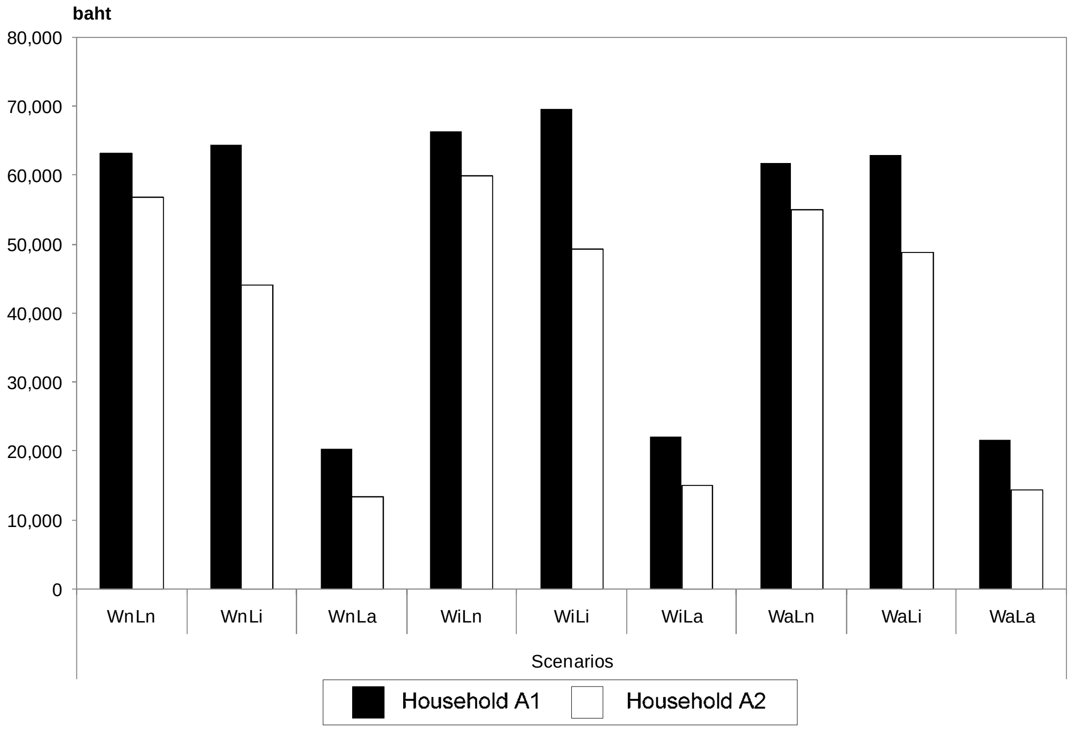


Figure 11.11 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) household hired wage employment per household per scenario.

Number of migrants

The number of seasonal migrants is clearly influenced by the availability of hired farm workers from outside the virtual village. As shown in Figure 11.12, when farm workers from outside are unavailable (scenarios with *Ln*), the seasonal migrants is significantly lower than when farm workers from outside are available. This could be caused by an indirect effect of more household income received from wage employment on migratory patterns.

However, the effect of water availability on labour migration is not clear. Only when considering the *Ln* set of 3 scenarios, it can be notice that when assigned with ponds plenty of water (*WaLn*), small holders have more seasonal migrants. Anyway, further investigation is needed to deeply examine the interaction between water availability and labour migration.

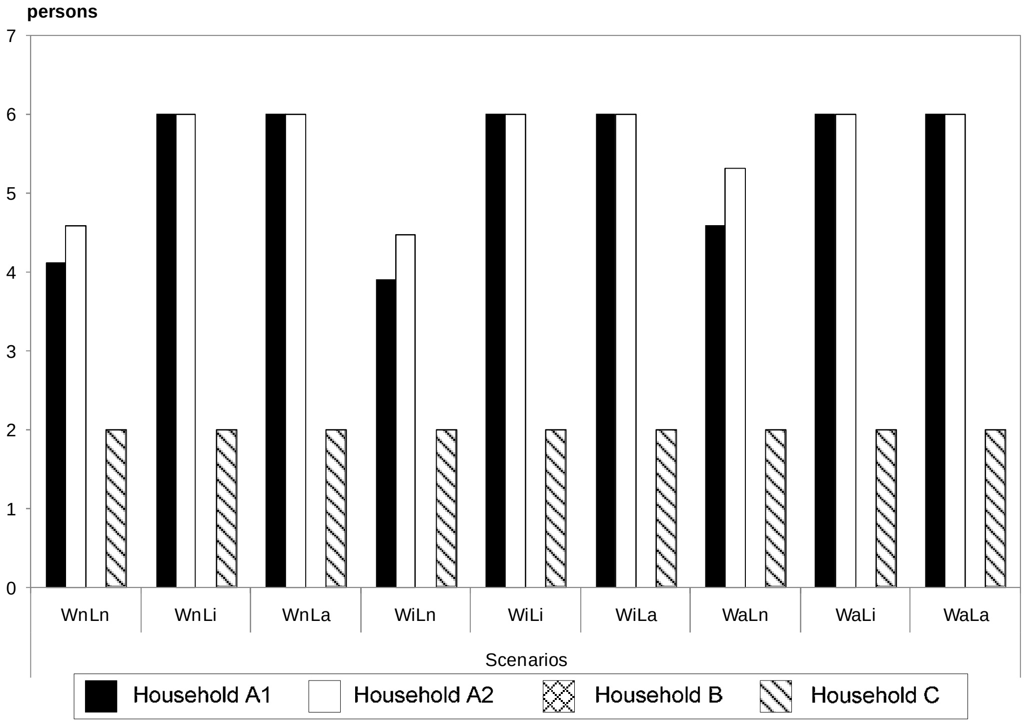


Figure 11.12 Average (over 19 simulations under different climatic conditions) of accumulated (over 5 years) number of seasonal migrants per household per scenario.

The monitoring and evaluation of this ComMod process is presented in the next chapter. It deals with the assessment of the ComMod effects on participants, mainly different types of local rice growers and the analysis of effects across farm types.

CHAPTER 12
ASSESSMENT OF COMPANION MODELLING EFFECTS IN LAM DOME YAI WATERSHED CASE STUDY

Under the Agriculture et Développement Durable (ADD) ComMod Project (2006-2008), a series of monitoring and evaluation activities to evaluate the diverse effects of ComMod process on participating farmers at Lam Dome Yai was conducted after five successive participatory workshops held in Ban Mak Mai village. This evaluation was mainly carried out by Ms. Manitchara Thongnoi as part of the requirements for her Master degree in Integrated Farming at the Faculty of Agriculture, Ubon Rajathanee University. Three tools were used for data processing: observations, interviews and story telling. The data analysis started at the coding of the transcripts to build families of codes corresponding to different types of effects. Afterwards, the analysis process of effects per type of farm, across farm types and for other categories of stakeholders (TAO, extension worker etc.) was carried out. For more details, see Thongnoi (2009). This activity started on April 2006 after the 2nd participatory modelling workshop had been organized in Ban Mak Mai village, Det Udom district, Ubon Ratchathani province. Since then, after each workshop, the monitoring and evaluation activity was executed as successive field investigations to analyze the effects of ComMod on participating farmers.

The quality of transdisciplinary research was also examined, especially: (i) the fit of the ComMod process to the local context, especially its legitimacy, and (ii) the knowledge sharing, and the local ownership of the ComMod process. The analysis of the immediate effects of the ComMod process was carried out to look into effects among the participating stakeholders, mainly different types of local rice growers. ComMod effects on participating farmers are presented in the first section of this chapter, followed by the analysis of ComMod effects across farm types.

12.1. ComMod Direct Effects

12.1.1. Learning about the Issue Being Examined

The ComMod activities helped the participants to better understand their interconnectedness in the village. Participating farmers realized that the migration situation created labour shortage at the household and village level. Public water infrastructure, such as community ponds and irrigation canals, could also cause conflicts among villagers. The ComMod activities motivated participating farmers to share ideas regarding future water resource development and also how to avoid possible water sharing conflicts. One suggested way for minimizing conflicts would be for the villagers to engage actively in water improvement schemes before any contractual commitments were made. Participating farmers were also stimulated to think about how to better manage rice transplanting in relation to variable water availability (in farm ponds and rainfall).

The ComMod process facilitated the sharing of knowledge, and as a consequence, learning of new agricultural practices. During the ComMod process, more experienced farmers (often older ones) transferred their traditional farming knowledge to younger ones while discussing their choices of actions. The ComMod activities helped participants to integrate academic knowledge communicated by the research team into their mental models of RLR farming practices, in particular knowledge about RLR growth and farm pond water levels brought about by variations in rainfall. As a result, the participants now think that they are better prepared to face drought; they have learned how to plan for rice establishment and the use of water from their small ponds more effectively.Moreover, some of them started thinking about actually recording farm expenses, which would help them formulate better plans for their rice production. Regarding labour migration, participants still believe that water improvement schemes alone could not effectively alter their decision to migrate because based on their experience water has never been adequate enough for year round farm production.

12.1.2. Social Learning Effects among Participants

Change in own and other participants' perceptions

Participants now have heightened aspirations to practice mixed farming and improve water supply. They also aspire to work in different jobs instead of working only on the farm to increase their household income. As a result of the collective learning process, participants have a better understanding of the diverse farming situations within their community; this includes an understanding of the reasons behind labour migration across farm types.

On individual behaviour

The step-by-step simulation of the rice production cycle stimulated the participants to think more quickly because a variety of aspects kept evolving continuously during the gaming and simulation sessions forcing the participants to keep up with what was happening. These activities and ‘what if’ questions asked during the sessions, supported the improvement of the participants’ communication skills and critical thinking ability, leading to behavioural changes.

On communication and networking

The participants agreed that knowledge shared about the issue at stake in the process was more useful than individual attempts at learning. Several participants declared that these activities made them realize the importance of village level discussions and collaboration to achievebetter mutual understanding when dealing with the community affairs. As a result of the ComMod activities, the participants have become more confident when communicating and sharing their ideas with other people. They also became more eager to learn and accept different points of view. However, they pointed out that the ComMod activities were limited to a few people directly involved in the process. Thus, a grater diversity of participants would be needed to provide a broader base of ideas on community situations. In addition, the details of the ComMod process were not easy for the older participants to explain to non-participants; but this was not the case for younger participants who were able to disseminate their ComMod experience within their friendship networks.

On decision-making, actions and practices

After taking part in several knowledge exchange activities, private water resource improvement and adoption of more rice varieties has been observed among some of ComMod participants. The attempt to use the direct seeding technique instead of transplanting, in an effort to tackle the problems of labour constraints, has also been noticed for a type A farmer once her migrant workers did not return to help producing rice during the prolong drought 2005-2006 crop year. But change in decision-making, actions and practices have not yet been observed among the participating farmers who suffer from labour problems as a result of migration.

12.2. Capacity Building

Before the workshops, participants said they would simply copy the farm practices of others; now participants feel that ComMod has taught them to reflect on farm dynamics, anticipate the consequences of possible farm practices, and consciously decide what farm practices are best for their future. At the individual level, participants have learned to think through a greater range of possible farm practices in order to adopt better farm strategies. At the collective level, they have learned ‘to exchange experiences and opinions’ and ‘to consider each others’ situations and perceptions when discussing future farm options’. The presentation of the ABM model by representatives of participating farmers to UBU students can indicate the improved capacity to communicate by providing more articulated explanation during discussion (see chapter 8 for more details of this seminar). This presentation also indicated the strong sense of model ownership making the participating farmers comfortable and confident to use it.

12.3. The Effects of ComMod across Farm Types

The ComMod activities had different kinds of effects on the different types of participating farmers, as observed through a series of individual interviews with players conducted just after each main field workshop. Below, only the interview data obtained from a sub-group of seven farmers (from eleven), who were the most at ease during the gaming and computer simulation activities, are shown. Farm types A, B, and C were represented by four, two and one farmers respectively.

Farm type A: Very small rice-based, resource-poor farms

In the case of type A, resource-poor farmers, new agro-ecological knowledge gained from the collaborative modelling process dealt with the effects of rainfall and water availability on rice production (Table 12.1). Although technical aspects were not explicitly examined in this experiment, the exchanges taking place among the participants seemed to have led to the acquisition of new knowledge in this field as well; for example, on direct seeding of rice and undertaking vegetable production after rice.

These small farms are often under-employed and look for off-farm and non-farm wage-earning jobs as migrant workers. Therefore, it is not surprising to see that they also found an interest in getting a better understanding of the migratory habits in the village during the ComMod process. This type of participating farmers mentioned two interesting opportunities that emerged from the ComMod learning process. The first one was the possibility to diversify their agricultural production out of RLR into vegetable cash cropping after rice. Another opportunity dealt with the possibility of exploiting underground water to increase the volume of the resource available for farming activities. However, this was not explicitly discussed with the research team during the field workshops but among the participants through informal exchanges during and after these short events. This might be an indication of how the participants' have recognised the usefulness of sharing ideas and knowledge among each other to generate such opportunities. Moreover, they wish to better understand the market opportunities for their farm products. Also, they would like to acquire a better understanding of the various commodities they can grow and so be ready to increase and diversify their agricultural production if more water were to be made available.

Type B farmers: Medium-sized rice-based with more market oriented farms and mixed farming practices, and type C farmer: large-sized market oriented farms and diversification out of rice or high remittance

These participating farmers represented the larger holdings which are the most affected by the lack of labour during the peak periods of labour demand in RLR production at transplanting and main harvest of late-maturing varieties. Table 12.2 summarizes the ComMod effects on these two farm types. It was not surprising to hear the more well-off type B and C farmers mentioning mainly economic aspects and especially the effects of a shortage of labourers on the economic results of RLR production as their keen interest in the simulation exercises. Like type A farmers, type B and C farmers have emphasized their wish to better understand the market opportunities for their farm products.

Table 12.1 Various ComMod effects on type A resource-poor farmers who participated in the collaborative modelling process in the Lam Dome Yai watershed, Ubon Ratchathani province (2006-2008).

Farmer	*A1*	*A2*	*A3*	*A4*
1. Knowledge acquisition				
Agro-ecological	• Water availability in relation to location of paddy fields • Change of water level in field/pond depending on rainfall	• Water availability in relation to location of paddy fields	• Impact of rainfall distribution on rice production	• Impact of drought on rice production
Technical	• Use of direct seeding in very dry year	• Different rice-growing practices between upper and lower paddies • Use of pond to grow rice	• Vegetable production for sale in dry season	• Drought mitigation by having more ponds to store water • Integrated farming practice
Economic	• Benefits of better access to water	• How to share land between RD6 (for family consumption) and KDML105 (for sale) rice varieties		
Social		• Labour migration situation in the village		• Labour migration habits in the village
2. Change in own perception				
Want to improve	• Better estimate of farm income • Understanding the relationship between farm products and markets	• Understanding the relationship between farm products and markets		• Want to build a pond
Capacities	• Better prepared to face drought • Timing of water pumping from ponds for higher benefit	• Better plan for rice transplanting • Better prepared to face drought		• Negotiation is needed to avoid water sharing conflict
Opportunities	• Possibility to grow vegetables after rice • Underground water more suitable than irrigation canal • Sharing my ideas with other farmers	• More income could be made during the dry season • Sharing knowledge is better than using only own one	• Underground water is suitable for my farm	• Integrated farming practice • Pond and underground water is suitable for my farm
3. Change in perception of others	• Better social networking in the village		• Sharing knowledge and ideas helps to understand other participants' farm management skills	
4. Change in decision-making	• Retain family labour to work on-farm if more water is available	• Will produce more farm commodities if more water is available	• More family labour to work on-farm if more water available	• Build a new pond or improve the existing one to store more water • More family labour to work on-farm if more water is available
5. Change in behaviour	• More sharing of farming ideas with other farmers	• Spend more time to work in paddies		
6. Change in action (s)			• Returned to rice production instead of leasing the land to neighbours • Started to grow vegetables in dry season	• Use direct seeding technique for rice production

Table 12.2 Various ComMod effects on medium sized type B and large type C participating in the collaborative modelling process in the Lam Dome Yai watershed, Ubon Ratchathani province (2006-2008).

Farmer	*B1*	*B2*	*C*
1. Knowledge acquisition			
Agro-ecological	• Relationship between rainfall and water level in field and pond • Sheduling of rice growing cycle in relation to water availability	• Difference between sandy and clayey soils in relation to water availability in paddy fields	
Technical		• Rice transplanting practice in relation to field location • Usefulness of having ponds and time to use water from them	• Rice production in relation to water dynamics in paddy field and pond depending on rainfall
Economic	• Low production because of lack of labour to look after rice	• Impact of labour shortage on farm production	
Social	• Labour migration patterns in the village		
2. Change in own perception			
Want to improve	• Better estimate farm income and investment • Understanding the relationship between farm products and markets	• Want to understand rice trading system	• Understanding the relationship between farm products and markets
Capacities	• Timing of water pumping from ponds for higher benefit	• Make annual farm operation plan	
Opportunities	• Learn to merge academic agricultural knowledge with own experience		
3. Change in perception of others			
Capacities		• Negotiation process regarding water sharing	
Opportunities			• Observe and analyze the actions of other farmers whose means of production are similar
4. Change in decision-making		• More family labour to work on-farm if more water is available	

The participating farmers said that the ComMod approach enabled them to discover the dynamics of the farm system (regarding time, water, labour management) and to think more intensively about their farming activities. This proved that farmers with only basic primary education can understand and learn from the gaming and simulation modelling approach, which is often perceived to be too complicated for local farmers.

It must also say that this is valid for the research team too; its members learned a lot from these exchanges, especially about farmer decision-making processes related to the adaptation of RLR production practices under varying rainfall distribution, and the management of the labour force on the different types of farming households. Through its evolving, iterative, collaborative modelling, the ComMod process has enhanced my understanding regarding the interaction between land & water use and labour migration at the study site.

But not all the representatives from the eleven farming households could be active participants, feeling comfortable in the simulation workshops. While the gaming sessions were more inclusive, the participatory simulation sessions were obviously more difficult to follow for some of the older, both male and female, farmers. More attention should be given to the participant selection process, especially in this type of community with many “skipped” families.

Even at this stage, some farmers mention limited changes in their decision-making, behaviour and farming practices as a result of their participation in the ComMod activities. Nevertheless, ComMod activities did generate a variety of effects on participants of this experiment, confirming the hypothesis that such an interactive collaborative modelling process can trigger both individual and collective learning through the intensive exchanges facilitated and stimulated by the evolutionary gaming and simulation models used throughout the process. Based on these findings and in agreement with the evolving and continuous characteristics of the ComMod approach, it can be said that new ComMod activities focusing on the commercial diversification of farm production in relation to water availability would certainly meet the interest of these collaborative farmers.

The conclusion is drawn in the next chapter. The outcomes of this ComMod process and its tools used are discussed. Some recommendations to improve the process and the future prospective research are also made.

CHAPTER 13
DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This ComMod experiment was conducted to improve the understanding of the interactions between land /water and labour migration through the co-design of an ABM with local RLR farmers in Ban Mak Mai village, Ubon Ratchathani province. Key associated tools, such as RPGs and ABM, produced during this ComMod process, were used to facilitate co-learning and to enhance the capacity of expression of the diverse field collaborators. There was no explicit conflict of resource use in this case study. Consequently, no attempt to facilitate a collective decision-making process over the issue being examined with the stakeholders was implemented. The focus was on achieving a joint understanding of the complex system under study.

In this case study, the legitimacy to start this highly interactive co-learning process may be criticized because there was no realistic perspective on attaining concluding decisions and action bearing concrete benefit to the participants. At the origin of this ComMod experiment, there was no clear demand from the local stakeholders or decision-makers at a higher level. Although the issue examined is widely recognized as an important one impeding rural development in this area, this ComMod process was exclusively initiated by a research team interest and its length was due to the long process of this doctoral research. The discussion is made of 2 parts and deals with initial diagnosis and ComMod phases, with special interest on stakeholder involvement throughout this experiment. The conclusion and recommendations follow at the end of this chapter.

13.1. Initial Diagnosis Activities for Preliminary Analysis and Field-based Knowledge Acquisition

13.1.1. Preliminary Synthesis/Diagnosis and Data Collection

This phase comprised the literature review, analysis of recent agricultural transformations, and farm survey to produce a household-based APS typology. As previous experiments on the management of upper watersheds of Northern Thailand have shown (Barnaud, Trébuil et al., 2008), this study found that initial diagnosis activities were essential for the researcher to understand the system especially the key question to be examined, get used to key informants and avoid possible pitfalls, in particular the balance of different stakeholders involved and their power relation prior to launch the ComMod process. In this case study, these preliminary findings were very useful to select the study site and the participants, to provide a baseline for ex-post evaluation, and to build the initial conceptual model.

Many invited participants did not join in the first RPG session in July 2005, since they were busy in their paddies. I had to find new participants and replacements were selected based on the farmer typology. This unexpected event challenged my preliminary findings because 7 out of 11 farming households participating in the first RPG session were not the same ones whom I regularly visited before launching my ComMod process. But their behaviour and actions during the gaming session showed that decision-making processes of farm belonging to the same farm type were not different. However, this event made objectives of the activities unclear to these new participants. Besides, a better-off farmer (sub-type C) did not join this RPG session as well as the following ComMod activities as planed. The absence of expected participants could indicate that more intensive sensitizing activity should be carried out to clarify the objectives of activities, and to increase participants' interest to take part in the collaborative modelling process. Besides, the date to organize the first RPG session was also a reason for this unexpected event as many farmers were preparing their paddies in the early part of the rainy season. Even if local farmers agreed on the workshop dates, they finally decided to work in their paddies since successive rainy days had occurred just before.

13.1.2. Study Site Selection and Types of Participants

The choice of this single village to carry out the ComMod activities could also be criticized as it could not represent all farming situations in the Lam Dome Yai watershed. However, taking into account that this large village has a relatively extensive diversity of farming units as shown in previous on-farm studies, the absence of explicit social conflicts that could complicate the process, and the local logistical constraints, this choice was considered as acceptable. Being driven by a dominant diploma training purpose, a wider range of stakeholders was not made. But representatives of the local TAO administrative body, agricultural extension service, and NGO attended the first RPG session as observers. No attempts were made to involve them more actively in the subsequent activities. The local extension worker suggested to invite representatives of several public organizations to take part in this ComMod process. But the choice was made to work with the villagers first, and to let them decide when and who they would like to invite to take part in the process. But, in this case, only migrant workers were suggested by participants since they would like to share their representation with the returned migrants. No suggestion to invite representatives of states' agencies was made. It was due to the fact that the participants did not feel that the issue being examined was so explicitly problematic to their livelihoods that they had to share with other stakeholders to find solutions. Therefore, only the diversity of local farmers was taken into account.

Nevertheless, the husbands and wives representing the different categories of RLR growers in the village were invited. This decision made was based on the fact that many strategic decisions at the farm level are made either by the farmer or his wife, or are discussed between them before a final choice is made. Culturally, Issan people give a high level of decision-making power to the wives in the management of the farming, social and economic activities. As seen in this ComMod experiment, the female participating farmers tended to dominate the proceedings and led lively discussions during gaming and plenary sessions.

The drawback of less diversity of stakeholders involved simply limited the diverse representations integrated in the model. As a result, the boarder knowledge base that participants were supposed to perceive through the knowledge exchange activities was not reached. However, if more diverse stakeholders involved had made available, the model produced would have been more complex, and needed longer implementation. Besides, it would have been difficult and very time-consuming to get the collective agreements on parameters and their values once the model was being fine-tuned with more stakeholder diversity. Or, it might even be impossible to co-construct the model with them.

13.2. ComMod Process in the Lam Dome Yai Watershed

13.2.1. Knowledge Sharing Activities

As several previous ComMod experiments have shown (Trébuil et al., 2002), this study found that the non-threatening and playful atmosphere of knowledge sharing activities (RPG and ABM simulation sessions) triggered lively discussions on topics people usually did not talk about. Indeed, it is quite surprising to see that farmers living in the same village usually do not have such opportunities to share their farming experiences and reflect on them. However, this emerging communication platform was only temporary because nobody was in a position to take over to continue this kind of activity in the village. Even if the group of farmers seemed to enjoy these activities, they did not develop a stronger network among them due to the lack of interdependency among the villagers with regard to the issue being examined.

Although all the organizational and technical aspects (schedule of activities, conception of the tools, etc.) were decided by the research team, the key tools used in this collaborative modelling process were not difficult for participating farmers to understand because, they mentioned, these tools represented their current farming situations. As a result, they quite naturally engaged themselves into the model design and model use phases.

13.2.2. Tools Developed and Used through the ComMod Process

13.2.2.1. Role Playing Game (RPG)

The participatory modelling workshops using RPGs were not prepared to facilitate the communication among participants. These RPGs were mainly designed to validate and improve the research team's knowledge regarding RLR management and labour migration practices. As a result, few interactions among the participating farmers were observed during the gaming sessions. But, more lively discussions occurred during the following plenary sessions. Particularly, when a gaming session was replayed by computer simulations, participating farmers could observe and comment other players' actions during the gaming session. During the evaluation, silent participants as well as talkative ones underlined the importance of these discussions as a way to exchange experiences, ideas and opinions in a well-structured way facilitated by a researcher. After these plenary discussions, people were still eager to continue to debate at home, with friends, but also beyond their usual social circles. However, several old participants encountered difficulties to engage in RPG sessions. Though it would require more time and other resources, the ComMod approach could have been more effective if more attention was paid to the participants having difficulties to get started. In addition to stimulate farmer communication and learning, RPGs were used to achieve two purposes: (i) validation of the conceptual model and (ii) farmer preparation for consecutive ABM simulations.

13.2.2.2. Ban Mak Mai Agent-Based Model (BMM model)

The convergence of logic, values and preferences between the research team and the participating farmers increased along the ComMod process, particularly when the process shifted from RPG sessions to the co-construction of the BMM model. Incorporating decisions and actions made in RPGs into the ABM increased the degree of contextualization, comprehensiveness and confidence, and participating farmers' comfort to use the model.

Different organization of farmer groups to co-design the BMM model

Because participants have different levels of knowledge and education, some of them could not quickly anticipate the consequences of interactions in the BMM model, and were influenced by others during discussions in large heterogeneous groups. It is also difficult for the research team to validate a model in group discussions with very diverse decision-making processes across farm types. In the small and more homogeneous groups, participatory simulations sessions generated critiques from farmers on the model more easily. They felt more comfortable to exchange experiences and doubts, focus on issues of personal relevance, and put more effort in learning about the issue at stake. They were also better prepared to address their concerns, visions and arguments once returning to join a larger group of diverse participants. Besides, the modeller could easily clarify key model parameters and precise their values within small groups of homogenous farmer belonging to the same type. However, the participatory simulations with all farm types were also important to examine interactions across types, particularly regarding hired labour management. This study found that the use of different groups of participants for model building provided complementary advantage and a more efficient way to construct and fine-tune the BMM model.

From realistic representations of actual households to the abstract concept of the Ban Mak Mai virtual farms

The first ABM (the LDY model) was introduced to the participating farmers in a workshop organized in April 2007. The LDY model represented the exact circumstances of the 11 households who participated in the process. During this workshop, I had difficulty to stimulate knowledge exchange to refine the model, and to get a collective agreement on the validation of this complex model. Therefore, the LDY model was simplified as shown in the latest version of the BMM model described in chapter 10. Although this latest version is more abstract than the first one, it was accepted by all the participating farmers who considered that it sufficiently represented the interactions between land & water use and labour migration in their village. I also found that the abstract representation could avoid the above-mentioned difficulty of asking for always more realism in the representations. The participating farmers acted like a group of RLR experts to assist computerized agents to produce rice. More lively discussions occurred and better model refinement was achieved.

Validation: a shared representation of the interactions between land & water use and labour migration

Validation relates to the extent to which the model adequately represents the system being modelled (Casti, 1997). According to the ComMod principles, the BMM model was built through the confrontation of the views of different types of stakeholders and the views of the researchers in order to clearly simulate scenarios built to explore the opportunities and dangers of an uncertain future (Moss, 2008). As a result, I found that participating farmers were able to identify and explore their scenarios of interest during computer simulations in May 2008 (see details in chapters 8 and 9). Such field activity was a proof of model validity accepted by participants. As a result, the participating farmers were comfortable and confident enough with the BMM model to present and comment this model in front of master students and scientists at the local university who did not participate in this modelling process during a special seminar at Faculty of Agriculture of UBU (see details in chapter 8). However, the discussion followed the demonstration in the special seminar showed that most of the students had different views and understandings and even concepts about RLR farming in northeast Thailand. This confirmed the fact that any model might be an accurate representation of some stakeholders' views, but at the same time, an inaccurate (though precise) one for other differing stakeholders' views (Moss, 2008). Nonetheless, this collaborative modelling practice is valuable because of its efficiency in communicating and therefore sharing such diversity of viewpoints.

13.2.2.3. Cost & Benefit

The designing process was long and costly, with only a very local impact so far. This inescapably raises the question of the cost-benefit of the whole approach. A couple of key events occurring in the village each year were insufficient to maintain a good momentum in the interactions between the research team and the local RLR farmers. Many factors dealing with the academic work of a Ph.D. candidate and the limited time available for collaborative gaming and simulation activities of the participating farmers impeded a faster implementation. As a result, I could not organize the workshops in the periods of peak labour demand in RLR production. The field workshops, especially for RPG sessions, were held mainly in April –May, just before RLR crop establishment, and again after transplanting and before harvesting in August or early October.

The RPGs sessions were definitely needed in this case study because it proved that they could offer lively discussion, inclusive outputs and prepare the participants to be ready to use the more challenging ABM tool. But, the preparation and organization of RPG sessions were costly. Once the BMM model was used as a knowledge sharing platform instead of RPGs, I could organize more interactions with farmers (4 times within 6 months) with less time needed to prepare them and to spend with participating farmers (usually half a day per workshop). Future ComMod sequence on this topic could be faster if the main tool used with the recent participating farmers is still the BMM model. Based on the ex-post evaluation, the participants said that they needed to learn the structure and operations of ABM through, at least two RPG sessions. Therefore, the RPG session may need to be organized if there is involvement of new participants.

13.2.2.4. Ownership of Tools and Process

The ownership of the process by the participants is still limited because they were not independently able to select the focus of the process and its successive phases. But, from the first RPG to the BMM model, there was a clear increase in the influence of participants' opinions and suggestions on the tools produced. Several of them suggested relatively major changes in the BMM model. For instance, the rules for nursery re-establishment once the first one failed were modified as suggested by participants. It was clear that the participants felt that they partly owned the BMM model and comfortably used it to communicate with other people like during their special seminar at UBU. Nevertheless, none of the participants was trained to be a ComMod practitioner in the village. As in a previous study (Barnaud et al., 2006), this study found that because of the participants' primary education level, it is not possible to transfer the conception of gaming activities and the computer modelling competences to such local actors. This concern about finding an autonomous and neutral local facilitator, who can continue to use the ComMod methodology and develop tools, remains a challenge.

13.2.3. Types and Number of Stakeholders Involved in the Process

ComMod is one of the alternative approaches used to facilitate communication because it motivates and engages all kinds of people in collective exchanges. Therefore, a greater variety of players involved in the ComMod activities is preferable. In this case, even if I established regular contacts with staff members of development-oriented institutions at the study site, there was no continuous presence of the project at the site. It was not possible to involve all of them throughout the successive model design phases due to several factors, in particular time constraints of the TAO officer and agricultural extension worker.

Due to limited space, time and equipment for players, 21 participants were considered suitable for RPG sessions in this ComMod experiment. During the BMM simulations, the number of participants was similar than in previous RPG sessions. But, I found that it was possible to use the BMM model to engage more participants in the same group discussion as shown in the special seminar given at UBU where more than 70 participants were involved.

13.2.4. Further Use of the BMM model

Based on the results from monitoring and evaluation activity, new ComMod activities focusing on market opportunities for farm products, and farm diversification out of rice in relation to water availability would certainly meet the interest of these collaborative farmers. However, integrating agricultural marketing dimension into the BMM model would require considerable time and the assistance of an economist but it could be proposed as a further sequence of this ComMod experiment. In term of out-scaling, the current model can be used as a communication tool in villages similar to Ban Mak Mai village to stimulate knowledge sharing, leading to the enrichment of the underlying conceptual model. I believe that the computer model could be introduced straightforwardly to other farmers without being perceived as a "black box" if its presentation is made by the BMM farmers themselves: there is no reason why the communication of the model among farmers would be more problematic than the communication of the model from farmers to scientists.

13.3. Conclusion

From this ComMod experiment, the understanding of the interactions between land/water use and labour migration across farm types is improved through the evolving iterative collaborative modelling process. We both researchers and participating farmers gained benefits through knowledge sharing activities. The initial diagnosis activities elucidate respective strategic decision-making processes regarding farm management and labour migration practices across farm types. This preliminary and field-based knowledge is very useful to design the initial conceptual model representing the structure and interactions of the components of the system under study. Based on the initial conceptual model, the RPGs and co-construction of the BMM model with local farmers lead to the creation of a common understanding and shared representation of the interaction between land/water use and labour migration.

Participating farmers can engage in the collaborative modelling process to co-design and co-construct models representing their system. The conceptual model is gradually collectively enriched through a series of participatory field works by using associated tools RPGs and ABMs. Using these tools can stimulate knowledge sharing, and open a way to integrate scientific and indigenous knowledge between scientists and the local farmers with primary educated level. The final ABM "Ban Mak Mai model" becomes a tool with integrated diverse knowledge presenting a shared representation of the system and the issue under study. The participating farmers are also capable to use RPGs and ABM to express their representations, to facilitate their collective assessment of the problem at stake, and to improve their coordination through the collective identification, simulation and assessment of scenarios of change. At the individual level, participants adopted a more reflective, pro-active style of farming, gained confidence in managing changes, communicated across broader social networks, etc.

Through the co-learning and knowledge sharing during series of participatory workshops, participants' adaptive management capacity was also generated. New ideas on how to improve the local agro-ecosystem also emerged, like the adoption of mixed farming and the complementary use of underground water. Some participants even declared having changed some of their farming practices as a result of this learning and exchange collaborative modelling process. The participating farmers can use the BMM model to discover the consequences of water dynamics interacting with fluctuation of labour availability. While the gaming sessions are more inclusive, the computer ABM-based participatory simulations are obviously more difficult to follow for the older farmers. This ComMod experiment enabled farmers to gain knowledge about individual farm practices. The interviews show that participating farmers think that they benefit at the personal level, especially by triggering individual learning, reflection and action about farm activities. The ComMod approach is very robust and efficient in its resemblance to reality, the fun, stimulating openness and exchange of experiences, while showing relationships between farm actions and their consequences.

13.4. Recommendations

13.4.1. On ComMod Process

Based on this ComMod experiment, there are suggestions to improve the process regarding the process management, and tools used.

13.4.1.1. Process Management

Involve diverse stakeholders as early as in problem formulation

More diversity of stakeholders, in particular local policy makers, is needed to integrate more diverse perceptions in this co-learning process. It is also to offer them to learn an alternative participatory approach to facilitate knowledge exchange between them and villagers. The selection of problematic issue should be legitimated by stakeholders and formulated with them. Taking these concerns into account can help to intensify the ComMod sensitizing activity. Clearer objectives to targeted participants prior the ComMod process can also be reached. The participants' age is specifically addressed in this case study. Elderly participants had to experience the RPGs at least two times before engaging themselves into participatory simulations. However, younger players immediately understood the ABM because they have higher educational background with experience in RLR management and computer uses.

Balance stakeholders' understandability and tediousness through repeated simulations

To ensure that local farmers had clear understanding about the model, the research team often repeated same simulations for a long time. The participants may sometimes be tiresome For example, an elderly man and woman of farm type A told me after they participated in the 24th April 2007 field workshop that "I feel that participating in this field workshop was similar to the last three workshops, it becomes repetitive and I did not learn new things" (Thongnoi, 2009). However, any change to increase participants' interest has to be carefully and collectively selected to avoid possible drawbacks, particularly individual subjectivity.

13.4.1.2. On Its Main tools Used

Role playing game

A RPG should not be very complicated with many steps to complete its session. The complicated RPGs may require some computer-assisted game plays, such as EXCEL spreadsheets and it, hence, necessitates to have assistants to help players. As a result, the players could sometimes be passive in the gaming session if they have to wait too long during inputs and output procedures operated by assistants. A simple RPG with few steps like the third RPG in October 2007 is more effective to always engage players into a game session. Besides, with more graphical pictograms used, and without use of computer-assisted game play, it is possible to design a RPG that allows the players to actively manage inputs and outputs by themselves. This kind of game design can keep the players focusing on the content of the game with more lively interactions.

Agent-based model

Based on the ex-post evaluation, experiencing and understanding the RPG's features and rules is an essential learning stage for new participants prior the use of an ABM. However, the pictograms used in the ABM has to be similar than those used in the RPG. The spatially-explicit representation in the BMM model is very helpful to support group discussions. But it has to be designed to present in a large size with high contrast and clear colours related to reality (e.g. deep blue for farm ponds) to be easily observed by all participants.

13.4.2. On Water Resource Development

The participating farmers confirmed their preference for the individual private water resource development, such as farm ponds and artesian wells. They see them as more feasible and practical. They do not reject an irrigation net work or public reservoirs but there are concerns about the equal access to these water resources for all types of farmers. They are also aware of water sharing conflicts that could emerge from unfair public water resource management and this could jeopardize the harmony of their village. The participating small farming households seem to be more pro-active to use any new water resources to diversify their farm production. They need more labour force to do so. Thus, they are likely to reduce the number of migrant workers if adequate water is made available. Such action may increase labour constraints on medium and large farms since hired labour from their main source would be less available. Thus, more water resources may not change their farming strategies to use it as much as expected. An important remark made by the participating farmers is that they would like to involve in local development prior to its implementation to avoid any pitfalls that may occur.

However, using the results derived from this experiment to improve the design of more adaptive future water management policies is still questionable because no policy maker was involved so far. Thanks to the up-scaling capability to reuse the BMM model by participating farmers, it is possible to engage local policy makers into a group decision. Besides, the BMM model can be used for out-scaling purpose if it is presented to other RLR farmers whose SAES is similar than the Ban Mak Mai village. This is also a way to steadily update the BMM model with local farmers. If the up-scaling and out-scaling are proposed, continuing this ComMod process is recommended to update and improve my understanding about the current situation with my field collaborators. This may lead to more concrete recommendations regarding possible future development derived from the collaboration between local farmers and other relevant actors.

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LIST OF ABBREVIATIONS

Acronym	Description
ABM	Agent-Based Model
ADD	Agriculture et Développement Durable
ALRO	Agricultural Land Reform Office
APS	Agricultural Production Systems
ARD	Agricultural Research and Development
BAAC	Bank for Agriculture and Agricultural Co-operatives
BMM	Ban Mak Mai village
BNs	Bayesian Networks
CAS	Complex Adaptive Systems
CGIAR	Consultative Group on International Agricultural Research
CIRAD	Centre de coopération internationale en recherché agronomique pour le développement
CM	Cognitive Mapping
ComMod	Companion Modelling
CORMAS	Common-pool resource Multi-Agent Systems
CPWF	Challenge Program on Water and Food
DAI	Distributed Artificial Intelligence
DSS	Decision Support Systems
GIS	Geographic Information System
INRM	Integrated Natural Resource Management
IRRI	International Rice Research Institute
IRRM	Integrated Renewable Resource Management
KDML105	Non-glutinous Khao Dawk Mali 105 variety
LDY	Lam Dome Yai watershed
MAS	Multi-Agent Systems
MCA	Multi-Criteria Analysis
M&E	Monitoring and Evaluation
NESDB	Office of National Economic and Social Development Board

NSO	National Statistical Office
OAE	Office of Agricultural Economics
ODD	Overviews, Design concepts, Details protocol
PET	Potential evapotranspiration
PS	Probability and Statistical method
RD6	Glutinous Rice Department 6 variety
RID	Royal Irrigation Department
RLR	Rainfed Lowland Rice
RPG	Role-Playing Game
RRD	Office of Rapid Rural Development
RRM	Renewable Resource Management
RS	Remote Sensed data
SAES	Social-Agroecological Systems
SD	System Dynamics
TAO	Tambon (sub-district) Administrative Office
TDRI	Thailand Development Research Institute
UBU	Ubon Rajathanee University
UML	Unified Modelling Language
V-E	Value-Expectancy
WaLa	4 farm ponds for all farms and 20 farm workers from other villages scenario
WaLi	4 farm ponds for all farms and 10 farm workers from other villages scenario
WaLn	4 farm ponds for all farms and no farm worker from other villages scenario
WiLa	2 farm ponds for B and C farms and 20 farm workers from other villages scenario
WiLi	2 farm ponds for B and C farms and 10 farm workers from other villages scenario
WiLn	2 farm ponds for B and C farms and no farm worker from other villages scenario

WnLa	No farm pond and 20 farm worker from other villages scenario
WnLi	No farm pond and 10 farm worker from other villages scenario
WnLn	No farm pond and no farm worker from outside scenario
WPI	Water Poverty Index

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Appendix 1 Regional distribution of poverty in the 9th National Economic and Social Development Plan

Currently, the Royal Thai government is developing an “area-based approach” to better pinpoint geographic areas where poor populations are concentrated. This project came under the management of the CDP-PAM (Country Development Partnership in Poverty Analysis and Monitoring) the World Bank, in collaboration with the Thailand Development Research Institute (TDRI), the Office of National Economic and Social Development Board (NESDB) and the National Statistics Office (NSO); the project’s main aim was to construct the first poverty map for Thailand using the World Bank method (Jitsuchon, 2001).

Region	*Province*	*Districts*	*Sub-districts*	*Target villages*	*Percent of target villages*
Northeast	19	320	1,878	6,676	39.9
North	17	193	1,235	5,806	34.7
Central	25	195	841	3,012	18.0
South	14	138	532	1,241	7.4
Whole Kingdom	75	846	4,486	16,735	100

Source: http://poverty.nesdb.go.th/Province/pov_area.htm the 9th National Economic and Social Development Plan

Appendix 2 Small scale irrigation infrastructure built in Lam Dome Yai watershed, Ubon Ratchathani province (1978-2002).

Completed in year	*Project name*	*Type*	*Location*		*Storage capacity*	*Irrigation area*	*Number of benefiting Households*	*Cost*
			Sub-district	*District*	*(m3)*	*(ha)*		*(x 1000 euros)*
1978	Beng Tha Chang	Reservoir	Tha Chang	Sawangweerawong	650,000	96	na	na
1980	Hua Pai	Weir	Rai Tai	Phibunmungsaharn	320,000	80	na	na
1980	Hua Kha	Reservoir	kang Dome	Sawangweerawong	322,000	160	na	na
1981	Hua Hin Siew	Weir	Kumkrang	Det Udom	108,360	32	280	60
1981	Hua La Long	Weir	Kumkrang	Det Udom	63,000	24	650	30
1981	Hua Oum	Reservoir	Na Chaluai	Na Chaluai	380,000	32	40	40
1981	Hua Sun	Reservoir	Na Chaluai	Na Chaluai	800,000	48	2,400	46
1981	Hua Bon	Weir	Song	Nam Yun	180,000	24	na	na
1982	Hua Ar Rong	Weir	Somsa-ard	Det Udom	320,000	80	534	33
1982	Hua Can	Weir	Na Suang	Det Udom	320,000	16	664	38
1982	Hua Lok	Reservoir	Na Chaluai	Na Chaluai	350,000	3	240	46
1983	Hua Can	Weir	Na Suang	Det Udom	320,000	16	170	38
1983	Hua Hin Siew	Weir	Phon Ngam	Det Udom	240,000	32	250	51
1983	Hua Bua	Weir	Klang	Det Udom	320,000	19	120	41
1983	Hua Chaluai	Reservoir	Na Chaluai	Na Chaluai	1,104,000	192	400	65
1983	Hua Pun	Reservoir	Ban Toom	Na Chaluai	1,354,200	32	100	66
1983	Hua Song	Reservoir	Song	Nam Yun	150,000	48	na	na
1983	Hua Sun (North)	Reservoir	Na Chaluai	Na Chaluai	530,000	na	na	na
1984	Hua Sadok	Reservoir	Na Yea	Na Yea	1,941,909	32	na	na
1984	Hua Damrong	Reservoir	Kee Lek	Nam Khun	1,457,311	96	na	na
1984	Hua Chorm	Weir	Kreng	Det Udom	320,000	32	160	42
1984	Kud Ngo	Reservoir	Muang Det	Det Udom	427,280	8	250	44
1984	Hua Pun	Reservoir	Na Chaluai	Na Chaluai	130,600	56	400	106
1984	Hua Non Yang	Reservoir	Tha Pao	Nam Khun	127,740	48	na	na
1984	Hua Rong Tan	Reservoir	Na Chaluai	Na Chaluai	200,000	80	na	na
1984	Hua Aum	Reservoir	Na Chaluai	Na Chaluai	853,000	80	na	na
1985	Hua Keng Aom	Reservoir	Na Reung	Na Yea	408,000	32	na	na
1985	Hua Bua	Weir	Klang	Det Udom	320,000	19	120	77
1985	Hua Aree	Weir	Nong Aum	Tungsriudom	320,000	8	na	na
1986	Hua Rad	Reservoir	Pu Pue	Nam Yun	416,800	32	na	na
1987	Hua Som	Reservoir	Phiboon	Nam Khun	214,476	160	na	na
1988	Hua Chaluai	Reservoir	Ban Tum	Na Chaluai	401,615	32	500	67
1989	Hua Som	Weir	Kud Rue	Tungsriudom	320,000	32	na	na
1989	Hua Tha Koy	Reservoir	Song	Nam Yun	910,000	48	na	na
1990	Hua Jan	Reservoir	Na Reung	Na Yea	267,000	320	na	na
1990	Hua Tiam	Weir	Non Somboon	Na Chaluai	320,000	32	190	107
1990	Nong Kd Vien	Reservoir	Ko Kong	Samrong	162,170	2	na	na
1991	Nong Kam Phak Wan	Reservoir	Sawang	Sawangweerawong	201,700	na	na	na
1992	Hua Bua Tiam	Weir	Klang	Det Udom	320,000	80	400	174
1992	Hua Ta Kod	Weir	Ban Toom	Na Chaluai	320,000	32	492	156
1992	Hua Som	Weir	Ko Saard	Nam Khun	320,000	80	na	na
1992	Hua Sun	Reservoir	Tha Chang	Sawangweerawong	4,040,000	16	na	na
1993	Hua Aree	Weir	Nong Aum	Tungsriudom	320,000	80	na	na
1995	Hua Karm	Weir	Meung Det	Det Udom	320,000	128	251	122
1995	Hua Fung Deang	Weir	Yang	Nam Yun	320,000	64	na	na
1997	Hua Fung Deang	Reservoir	Tha Kao	Nam Khun	320,000	64	na	na
2001	Hua Kao San	Weir	Na Suang	Det Udom	320,000	16	na	na
2002	Hua Som	Weir	Phiboon	Nam Khun	61,000	128	na	na

na: not available
Source: Irrigation Office, Region 7, Royal Irrigation Department, Ministry of Agriculture and Co-operatives, Ubon Ratchathani (2006).

Appendix 3 Materials used to produce GIS maps in this study.

Year	1973		1984	1989	1991	1995	1996	1999		2000	2002	
Types	Aerial photos	Landsat MSS	Aerial photos	Landsat TM	Land use map	Land use map	Aerial photos	Topomap (raster)	Topomap (vector)	Landsat ETM	Land use map	Landsat ETM
Date	20-Dec	3-Jan	18-Dec	25-Dec			28-Nov			31-Dec		20-Feb
Materials	pictures and scanned images	digital: 4 bands	pictures and scanned images	digital: 7 bands	digital file	digital file	pictures and scanned images	papers and digital files	digital file	digital: 7 bands	digital file	digital: 7 bands
Scale	1:40,000	60 x 60 sq.m.	1:40,000	30 x 30 sq.m.			1:50,000	1:50,000		30 x 30 sq.m.		30 x 30 sq.m.
File extension	GeoTIFF	GeoTIFF	GeoTIFF	GeoTIFF	ArcInfo	ArcInfo	GeoTIFF	GeoTIFF	dgn	GeoTIFF	ArcInfo	GeoTIFF
Sources	RTSD	http://glcfapp.umiacs.umd.edu	RTSD	http://glcfapp.umiacs.umd.edu	LDD	DEQP	RTSD	RTSD	RTSD	http://glcfapp.umiacs.umd.edu	UBU	UBU

Notes:

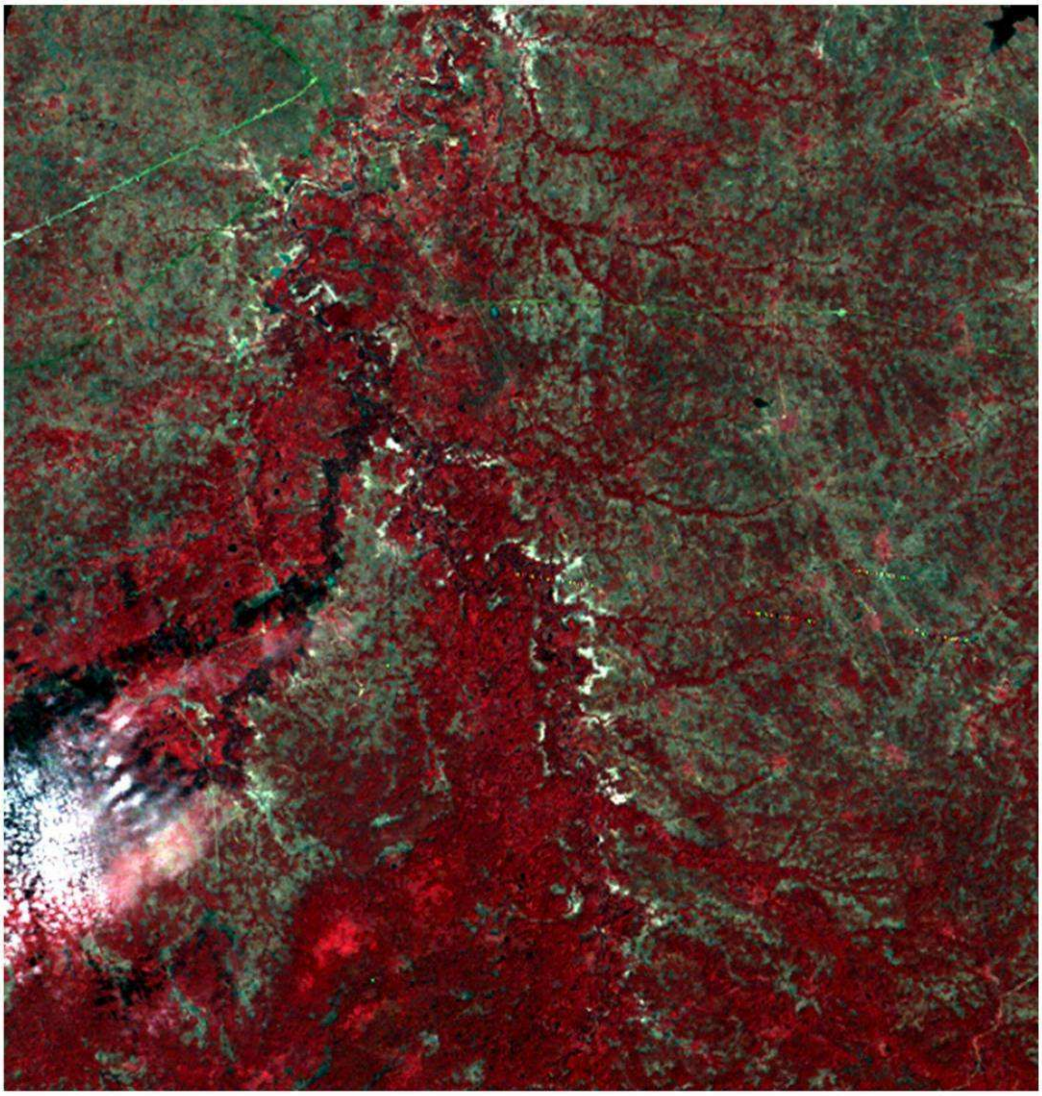
RTSD: Royal Thai Survey Department, Royal Thai Army, Ministry of Defence

DEGP: Department of Environmental Quality Promotion, Ministry of Natural Resources and Environment.

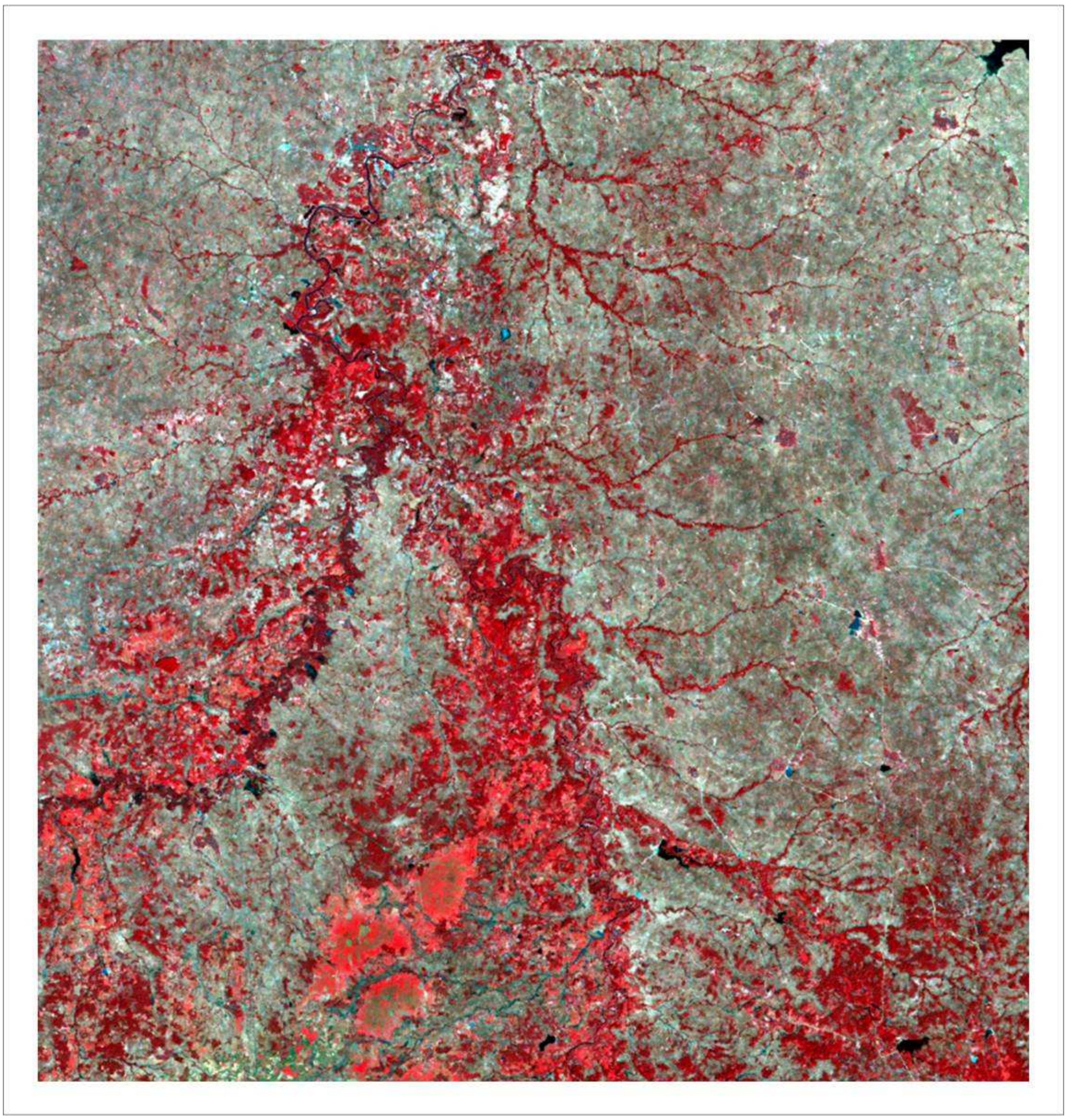
LDD: Land Development Department: Ministry of Agriculture and Coorperatives

UBU: Ubon Rajathanee University

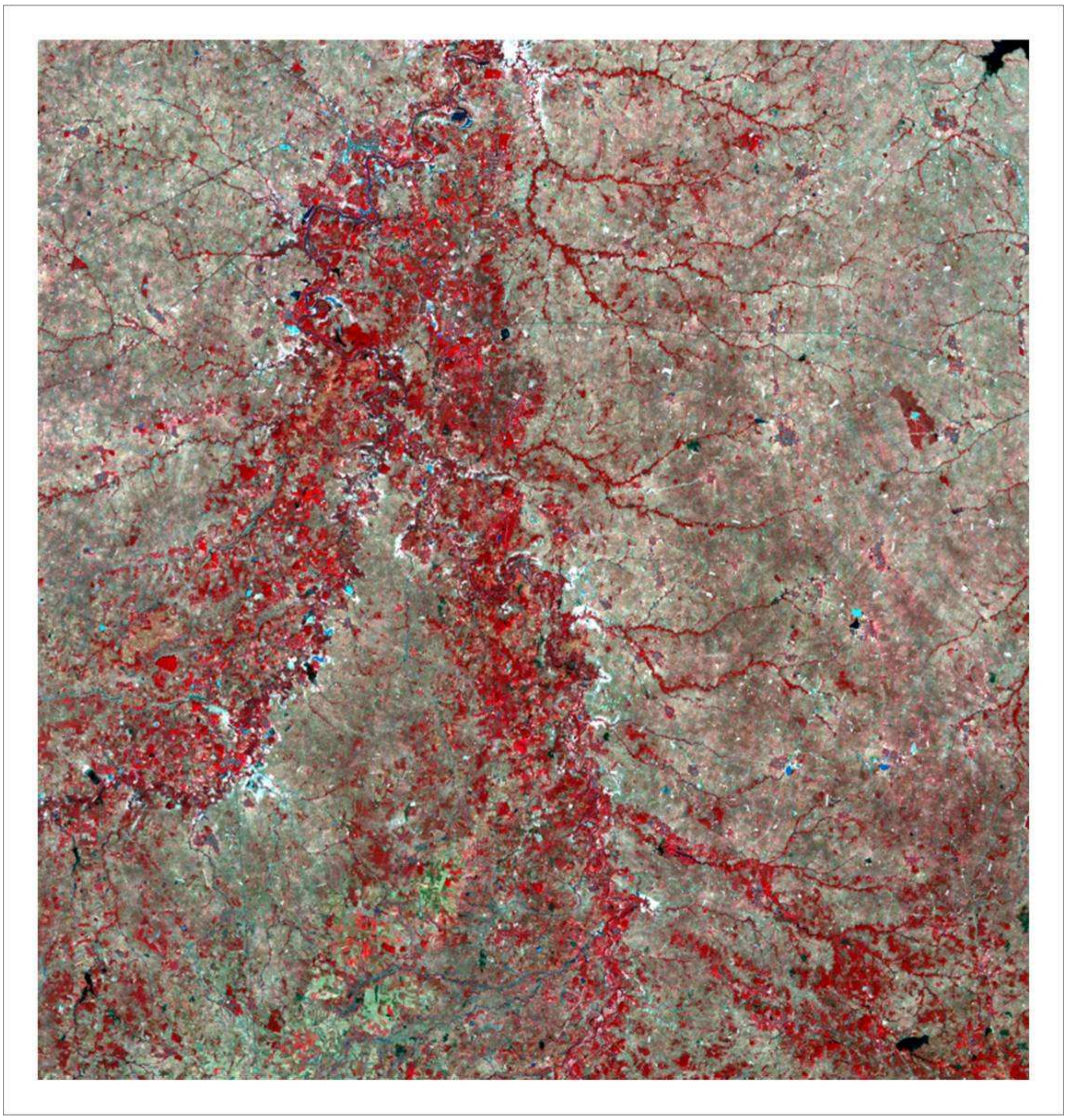
Appendix 4 Standard false colour composite band 1, 2, 4 of the study site based on the Landsat MSS image taken on 3 January 1973.



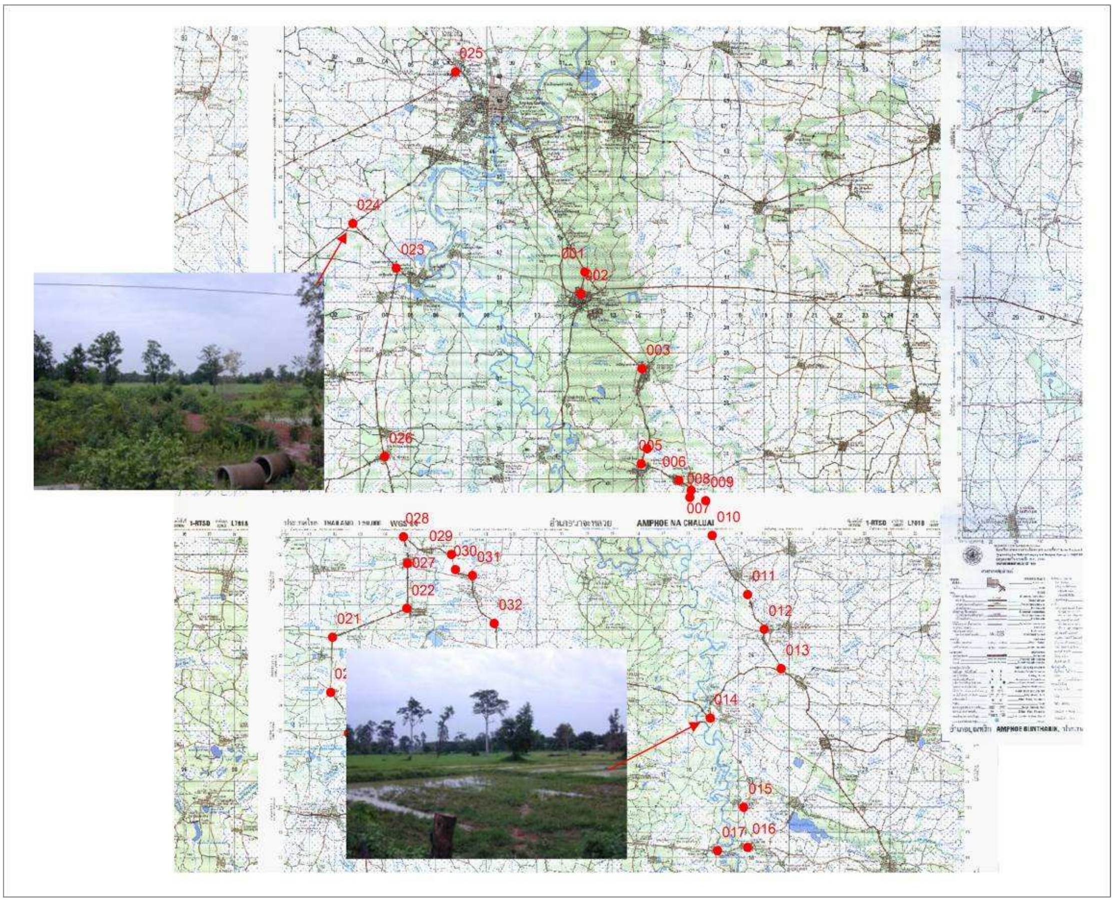
Appendix 5 Standard false colour composite band 2, 3, 4 of the study site based on the Landsat TM image taken on 25 December 1989.



Appendix 6 Standard false colour composite band 2, 3, 4 of the study site based on the Landsat ETM image taken on 20 February 2002.



Appendix 7 Ground truth and GPS operation carried out in the central part of Lam Dome Yai watershed on 11-12 August 2005.



Appendix 8 An example of determining factors and conditions of the combination of productions completed after the farm survey in April and August 2004.

THE FAMILY (members): 4 persons: 1 male (52 year old), 3 females (48, 7 and 4 year old)

ITS OBJECTIVE: Self-subsistence and pay debt

LAND OWNERSHIP (own, rent, lease)
Own (land reform): 2.24 ha (14 rai).
Rent (land reform): 1.76 ha (11 rai) from his brother.
There is a 18x30x2.5 m pond (water available all year round but they have to keep it for next rice season)

ECONOMIC STATUS
Annual income from rice: 20,000 baht
Annual remittance: 10,000 baht

Debt: Community cooperative: 19,000 baht
Village fund: 15,000 baht

Name:
Mr. Thongdee Thongtant (52 year old)
Year: Aug 2004
Address:
Moo 13 Ban Makmay, Tambon Klang, Det Udom, Ubon Ratchathani

The family leader is the only person taking care of rice production with the help of his son or his daughter who returns every year. Rice is the only labor-need activity this family does.

His brother is disable person. He has to look after him and take care of his land.

Income is used to reimburse the debt and daily expenses. They pay cooperative debt → borrow new loan → pay village fund debt → borrow new loan → use for daily expenses and capital for rice production next season.

LABOR SOURCE
Family labor: 1 main and 1 seasonal migrant
Hired labor: 20 transplanting and uncertain number for harvesting
Mutual help: No

FARMING AREA: 4 ha (25 rai)

FARMING AREA PER LABOR (F/L): 2 ha (12.5 rai)

PRODUCTION COMBINATION
- Rice (25 rai): Nursery-late April-pond → Transplanting-Aug-rain → Harvesting-Oct
- Rice mill: receive the service either rice or money

Debt, children and members' illness are pushing factors that some family members have to migrate to work in BBK. Migration causes labor shortage in family. When rice season comes, they need to hire labors. There are two conditions. 1st if a migrant returns, they hire labor only harvesting period. 2nd if no one returns, they have to hire labors for transplanting and harvesting (use remittance)
This family prefer to migrate to get higher income (the agency must manage everything) because they want to clear debt. However, they cannot do so because of the elders and grand children. Because of inadequate labor forces and water resource, they do nothing in dry season.

MIGRANT'S CHARACTERISTIC
1st daughter (6th grade-married-29 year old) / 2nd son (6th grade-married-live in Laey-27 year old) / 3rd son (vocational collage-single-24 year old)

LABOR FORCE
Constraints:
- F/L is high
- a main labor is old.
Potentialities:
- his daughter or 3rd son generally returns home during rice production
- use remittance to hire labors
- waged labors are available in the village

All labor forces (except Khun Thongdee) are not home. Two of them are seasonal migrants but they do not return home the same year. One returns. The other works in BBK. Some year, none returns up to the wage or salary they receive.
2nd son move out for good. He live with his family in Loey.
Purposes of migration
- need more income
- unemployment in village
- have own family

Friends and deprivation are important factor that encourage migration of possible migrants. The labor broker was an effective way to recruit villagers to sign contact and send them to Taiwan (not so popular way now because information is more easily accessible for villagers).

The satisfaction is pretty high because this household is not far from center (Tambon Klang) and about 20 km from Det Udom.

Migration begins because the necessity of using money for raising kids and curing the ills. At the same time, migration stops because a family member is too old or too young. Thus, they have to share their responsibility between persons staying home (do on-farm job) and persons migrating to work for higher income (wage).

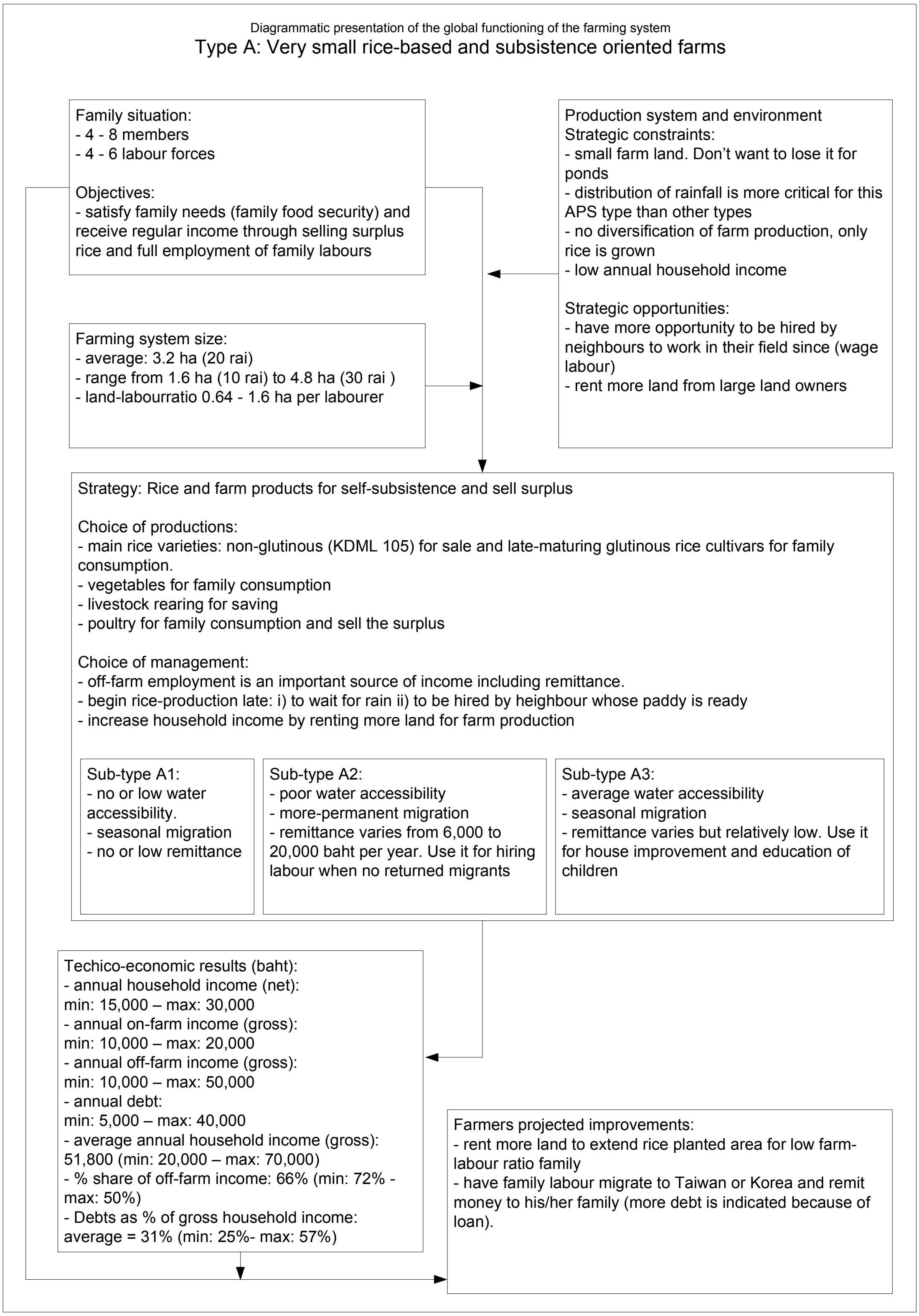
FAMILY MIGRATION NORM (decision makers, migration pattern)
- make decision together
- the parents want to have all members stay together
- seasonal migration

FAMILY AND FRIEND NETWORK (migration network, affiliation)
- friends' suggestion
- job classified news paper
- deprivation
- labor broker

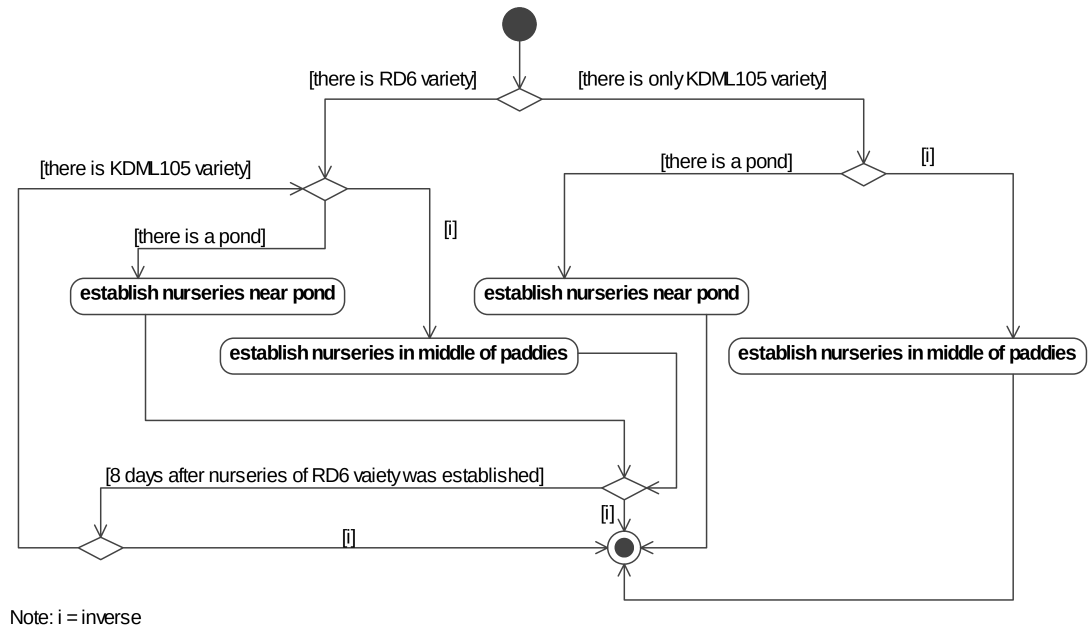
RESIDENTIAL SATISFACTION (public services, community size, household appliances)
- a secondary school
- public health service
- good road network
- large community size
- not many household appliances

MIGRATION HISTORY
- 1st daughter: 18 year old worked in BBK (maid) 4 years and returned home to get married (have 2 kids). Now work at a hotel in BBK.
- 2nd son: worked in Taiwan for 3 years. Came back and got married, Now live with his wife in Loey.
- 3rd son: worked in BBK. Changed many jobs. Stay with 1st daughter
- 2003, they all worked in Songkla 5 months

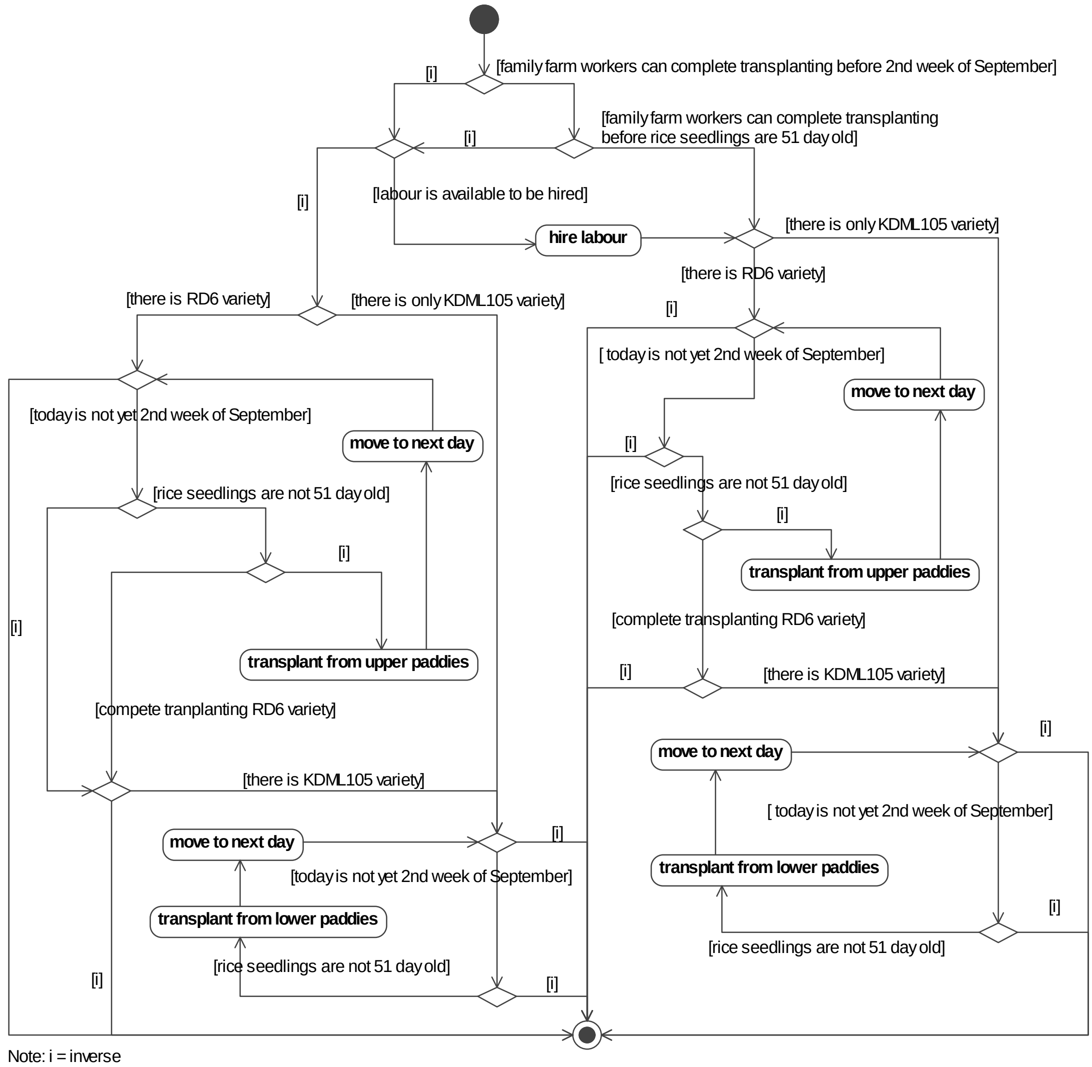
Appendix 9 An example of diagrammatic presentation of the global functioning of farming unit.



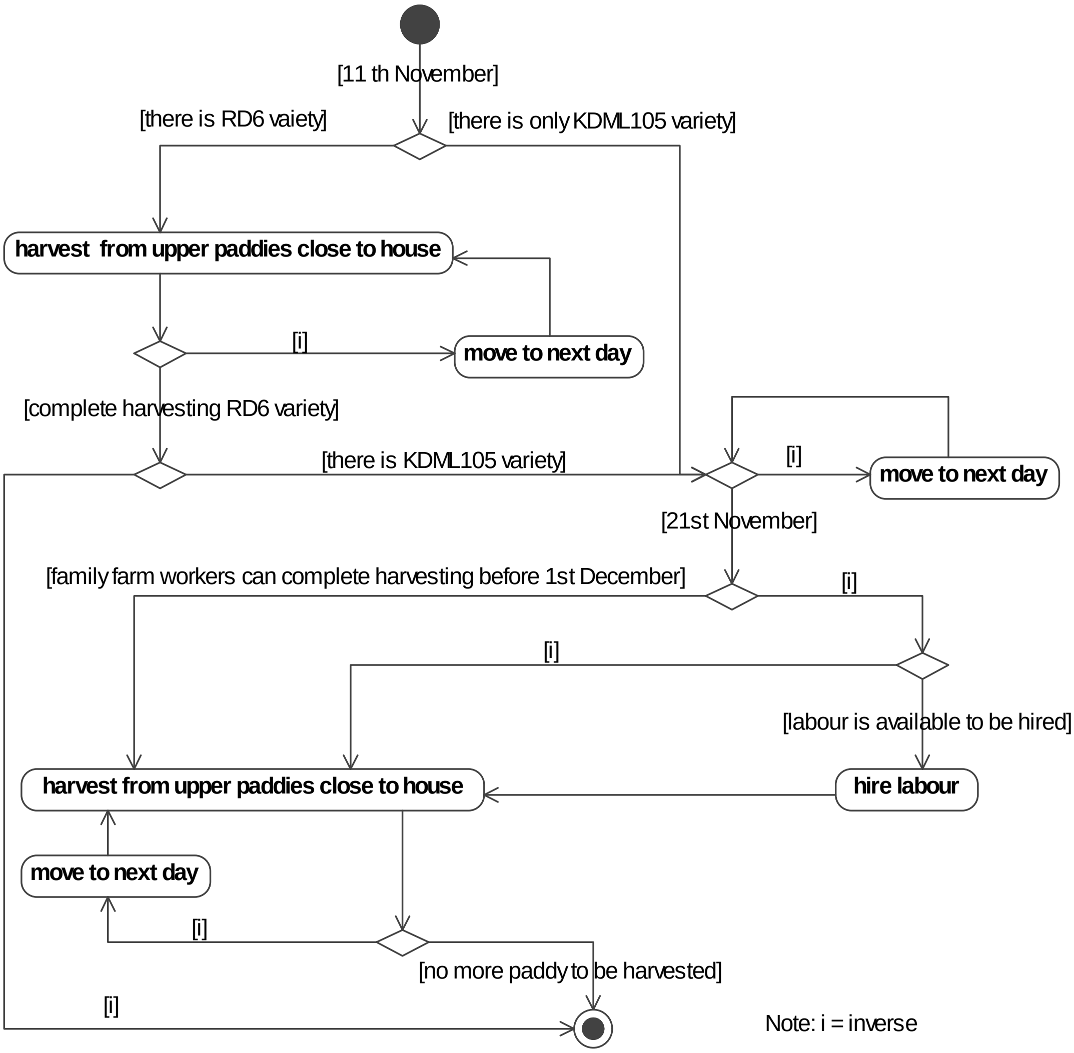
Appendix 10 Algorithm representing household decision to locate nursery for RD6 and/or KDML105 in a UML activity diagram.



Appendix 11 Algorithm representing household decision to transplant RD6 and/or KDML105 in a UML activity diagram.



Appendix 12 Algorithm representing household decision to transplant RD6 and/or KDML105 in a UML activity diagram.



BIOGRAPHY

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Full-time teaching in Landscape gardening, Principle of art for landscape design, Landscape design 1, and Digital design studio
Publications:
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Companion Modelling to analyze the land/water use and labour migration interactions in Lam Dome Yai watershed, Lower Northeast Thailand

SUMMARY

Rainfed lowland rice is the dominant type of land use in lower northeast Thailand. Rice production is constrained by erratic rainfall and coarse textured soils leading to low yields of the single wet season crop cycle, and very low per capita farm incomes. Labour migration is a common adaptive strategy of resource-poor rice farmers. A better understanding of the interaction between labour migration and land and water use is needed as the authorities plan massive investments in new irrigation infrastructure. This research used the Companion Modelling (ComMod) approach to facilitate co-learning about this key interaction between researchers and a heterogeneous group of local rice farmers. ComMod is an iterative and evolving approach that facilitates dialogue and shared learning through interdisciplinary action-oriented research to strengthen the adaptive management capacity of stakeholders. It was used to enhance co-learning among stakeholders through knowledge exchange to integrate indigenous and academic knowledge on rice and farm management. A long ComMod process, associating modelling tools such as Role-Playing Games (RPG) and successive versions of an Agent-Based Model (ABM), was implemented with rice farmers from Ban Mak Mai village in Ubon Ratchathani province. A shared representation of the interaction under study was achieved to be used for joint exploration of possible future scenarios. Farmers consider that the co-designed ABM, sufficiently represents their farm management and labour migration practices. They also found that such a process, stimulated by evolutionary gaming and simulation exercises, is effective to facilitate knowledge exchange and integration.

Key words

Companion Modelling, migration, Northeast Thailand, participation, riziculture, land and water use.

RÉSUMÉ

La riziculture inondée est l'usage des terres dominant au nord-est de la Thaïlande. La production d'un cycle annuel à faible rendement est contrainte par la distribution erratique des pluies et la texture grossière des sols, et le revenu agricole par tête est très bas. Pour les paysans aux ressources limitées, les migrations de main d'œuvre constituent une stratégie d'adaptation fréquente. Une meilleure compréhension de l'interaction entre ces migrations et l'usage des terres et de l'eau est nécessaire car les autorités planifient de grands investissements dans l'irrigation.
La modélisation d'accompagnement est utilisée pour faciliter le co-apprentissage de cette interaction entre chercheurs et différents types de riziculteurs locaux. Cette démarche itérative et évolutive favorise dialogue et partage de connaissances lors d'une recherche-action interdisciplinaire renforçant les capacités d'adaptation des acteurs. Elle est ici utilisée pour faciliter l'intégration des connaissances autochtones et académiques sur la gestion des rizières et des exploitations.
Un long processus de modélisation collaborative a associé des jeux de rôles et la construction des versions successives d'un modèle informatique multi-agent avec les riziculteurs du village de Ban Mak Mai dans la province d'Ubon Ratchathani. Une représentation partagée de l'interaction étudiée a été produite pour l'exploration conjointe de futurs scénarios. Les agriculteurs considèrent que ce modèle représente suffisamment leurs pratiques de gestion rizicole et des migrations. Selon eux ce type de processus, stimulé par des exercices évolutifs de simulation, facilite efficacement échange et intégration des connaissances.

Mots clés

Migration, modélisation d'accompagnement, participation, riziculture, Thaïlande, usage des terres et de l'eau.

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